Vision and Roadmap Eindhoven Energy-Neutral 2045
Research report energy in the built environment - June 2014

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This publication on the Vision and Roadmap Eindhoven Energy-Neutral in the Built Environment is produced by Elke den Ouden and Ruud Gal of LightHouse, solution partner of the Intelligent Lighting Institute at the TU/e, for and in partnership with the city of Eindhoven. Many experts and local stakeholders have contributed to the result.

The aim of this publication is to give a description of the desired future scenario to become energy-neutral in the built environment, as well as to plot possible routes. This description will be used to define further steps to be taken in public-private collaboration to achieve the desired future of Eindhoven in 2045.

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Eindhoven

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Introduction

Goal

Aim of Eindhoven

Eindhoven has set itself the goal of being ‘energy-neutral’ by 2045. To achieve this, a number of main themes are described in a document, which has been compiled on the occasion of the conference in February 2013 [Eindhoven, 2013].

Ensuring that this goal is actually achieved in practice will require cooperation between government, business and industry, research institutes and the citizens of Eindhoven. A series of short-term activities with a long-term focus will have to be defined. To make the goal achievable, Eindhoven will need a shared vision and roadmap.

LightHouse has experience in developing similar roadmaps for urban lighting and the future of education. Because of the interrelationships between these roadmaps, LightHouse has been asked to make a proposal for an approach to realise the vision and roadmap for Eindhoven energy-neutral in 2045.

Approach

To formulate the vision and roadmap, the project has been divided into a number of phases:

1. **Phase 1: Ambition**
   - Analysis of the current situation, the points of departure and the ambition level in both the short and longer term in relation to Eindhoven energy-neutral 2045. Defining the scope in terms of both the content and the involved parties.

2. **Phase 2: Vision**
   - Identifying the most important value drivers for the future developments in relation to energy and translating these into a future scenario for the City of Eindhoven. This phase focuses strongly on the societal aspects of innovation to enable effective and efficient implementation.

3. **Phase 3: Roadmap**
   - A roadmap study then considers which developments are possible and necessary, and also takes into account the social and societal implementation. This phase includes identifying the initiatives that are already in progress.

4. **Phase 4: Programme**
   - A roadmap forms the basis for a programme of projects and activities. In this phase, there is a strong need to translate the already available technologies into a soundly based implementation with maximum effect on energy neutrality, and to relate this to the necessary studies in terms of cost, time, creativity and management attention.
Challenges

Point of departure

The City of Eindhoven has carried out a detailed study of its ambition to be energy neutral in 2045, and published the findings in the publication ‘Eindhoven energy-neutral’ [Eindhoven, 2013].

"The municipality has set itself the goal of achieving energy-neutrality between 2025 and 2045. By energy-neutrality, the municipality means that energy demand must be limited as far as possible, and the energy needs within the city’s boundaries must be met sustainably. The municipality has set itself the goal of achieving this ambition excluding mobility before 2035, and to achieve the ambition including mobility before 2045."[Eindhoven, 2013].

Challenges

Achieving the ambition of energy-neutrality will only be possible with the contributions of all the involved parties. The energy used in Eindhoven serves a range of purposes, for example: comfortable living and working, industrial activity and mobility.

The challenges for achieving full energy-neutrality lie in a range of areas (see the figure on page 6):

- **Energy-saving**
  - Sustainable energy is scarce, and is expected to remain so for the foreseeable future. This makes energy-saving an important factor. To achieve it, the first thing that will be required is awareness among users (citizens, business and industry, and organisations), followed by real behavioural change. At present, not all those involved are convinced that the required awareness among citizens can be achieved effectively and efficiently.
  - Embodied energy
    - A significant part of the energy used in Eindhoven is needed by manufacturing industry. The products, which have a high embodied energy content, are sold and used not only in Eindhoven, but are also ‘exported’ outside the city and the region. In addition, goods produced elsewhere are used and the energy needed to produce these goods will need to be produced sustainably to allow the goal of energy-neutrality to be achieved in full. However this will require regulation (for example at European level), which falls outside the scope of this assignment.

Direct sustainability

- The use of energy gained directly from sustainable sources is the third important factor. To make this possible, it is important that ample supplies of sustainable energy are available. This is most of all an organisational challenge, to ensure that sustainable energy is generated and if necessary stored wherever it is technically and economically possible to do so. In many cases this will exceed the ability of a single organisation, making collaboration necessary – for example to use the batteries of electric vehicles for (temporary) storage of excess sustainable energy from solar and/or wind sources.

The transition from ‘grey’ to ‘green’ energy requires a carefully controlled process. Grey energy will still be needed for some time as a back-up for scarcity and fluctuations in the availability of sustainable energy. In the meantime, the challenge is to set up the business models in a way that makes the transition to sustainable energy attractive to the most important stakeholders.

- As well as the above challenges, which can be addressed at either a more generic or a more specific level, the question is what is the scope of the vision and roadmap should be. Should the drive to become energy-neutral be limited to the city boundaries, or does it extend beyond them? For example the Brainport region? The challenge lies in finding the right balance between independence and self-sufficiency on the one hand, and the opportunities that lie in collaboration with outside regions on the other hand.

Scope of the vision and roadmap

The scope of the vision and roadmap has been discussed and agreed in a workshop with the responsible executive councillors of the City of Eindhoven and management of ‘Woonbedrijf’, the largest housing cooperative in Eindhoven. The following elements were also defined at this time:

- The absolute amount of energy used is in itself not so relevant, as long as it is generated sustainably.
- The vision that is developed must be broad enough to support collaboration with other parties in the metropolitan area and to link them in their focus on sustainability. In this respect the city boundaries are not intended to serve as clearly defined limits.

- The focus in this assignment is on energy-neutrality in the built environment. At a later stage roadmaps can also be developed for mobility and industry, but these are not at present within the defined scope. However it is important where necessary to consider relevant interfaces with mobility and industry (for example for the storage of energy in vehicles).

- The goal of this roadmap is not to serve as a blueprint for the choices to be made in the coming years, but to create a framework which with increasing knowledge can be used to take decisions in line with ‘The Natural Step’.

- The aim is to define an exportable concept for Eindhoven, where the infrastructure must be local and matched to the needs of the region, making use of flexible networks and circular models.

Ambition

- The challenges were also defined at this time: Point of departure
- The goals of the roadmap are defined as follows:
  - Scope of the vision
    - Scope of the roadmap
    - Vision

- The first thing that will be required is awareness among users (citizens, business and industry, and organisations), followed by real behavioural change.

- Energy needs within the city’s boundaries must be met sustainably. The municipality has set itself the goal of achieving this ambition excluding mobility before 2035, and to achieve the ambition including mobility before 2045.

- The transition from ‘grey’ to ‘green’ energy requires a carefully controlled process. Grey energy will still be needed for some time as a back-up for scarcity and fluctuations in the availability of sustainable energy. In the meantime, the challenge is to set up the business models in a way that makes the transition to sustainable energy attractive to the most important stakeholders.

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The present energy situation in Eindhoven

Energy density of demand versus population per km²

Eindhoven has relatively little energy-intensive industry, only DAF and VDL which together account for around 1% of the total energy demand. Also in terms of energy density of demand, Eindhoven rates average at approximately 6.5 W/m², as shown on the page at the left. This influences the ability to export solutions, which can be developed in Eindhoven, to the city itself as testbed. In the “Eindhoven energy-neutrality” report, the average annual gas consumption per household is approximately 1537 m³, and the average electricity consumption is approximately 3460 kWh. About 75% of the energy consumed is gas, of which 75% is used for heating and 25% for hot-water supply. Gas consumption for cooking purposes is very low. Electricity accounts for the remaining 25% of the total energy consumption. Broadly speaking, the electrical energy used can be divided into 6 roughly equal categories (washing & drying, cooking & freezing, TV/audio/video/PC, lighting, and ventilation/cooking/other kitchen appliances).

An overview of local possibilities for sustainable energy technologies, especially in direct energy consumption, is given below.

Wind energy

The potential for the use of wind energy is limited by a distance of 1 metre.

Solar energy

The potential for the generation of solar energy (PV systems and solar collectors) could over time cover around 50% of the energy needs. This is based on the assumption that 20% of roofs are suitable for, and are actually used for, this purpose.

Biomass energy

A number of biomass energy-generating facilities are currently installed in Eindhoven. The fuel is wood products and bio-oil. The present capacity covers about 8% of the city’s energy needs. The possible use of fermentation had not yet been studied in 2011.

Geothermal energy

Eindhoven has a somewhat disadvantageous location for large-scale use of geothermal energy. Current expectations are that around 1% of the energy needs can be met from this source. However, the possibility that this percentage could become higher in the future should not be ruled out.

Thermal Energy Storage

Eindhoven currently has 30 TES (Thermal Energy Storage) sites. If TES only proves to be viable in new buildings and major renovation projects, its potential will be limited (1-3%). It is not only a technical challenge but above all a social challenge to create enough local support to make the building of a TES a practical proposition. In addition, building a ‘classical’ TES site is not entirely without concerns. However, current development may allow these problems to be circumvented.

Energy-saving

The estimate is that around 35% of energy consumption can be saved by changing behaviour and by technical measures, such as insulation, installations and domestic appliances, industry and mobility. 60% of the overall energy savings can be made by households, 25% by industry and 5% in mobility.

Energy balance

In household energy consumption, a saving of about 20% in grey energy consumption can be expected. It has been estimated that if no measures are taken in relation to sustainability, energy consumption will rise to more than 20 PJ by 2040. It is also estimated that on the basis of expected technology developments, an additional reduction of 3 PJ in the consumption of grey energy in Eindhoven can be expected. From these figures, it follows that there will then be a remaining demand for grey energy of approximately 8 PJ in 2040.

The total generation potential is estimated at 21% of the present energy consumption. This is based on the following assumptions:

• Today’s technology is used (not future technology)
• Wind energy cannot be used on a large scale because of the proximity of Eindhoven Airport
• Only locally available biomass is used as fuel
• Solar energy is only used on 20% of the roofs
• Only limited use is made of geothermal energy because of the ground structure
• The availability of waste heat is limited because of the low level of energy-intensive industry
• TES (Thermal Energy Storage) sites are only suitable for major renovation and new building projects

Energy-saving

The four System Conditions

In a sustainable society, nature is not subject to structurally increasing... 1. ...concentrations of substances that are produced from the earth’s crust 2. ...eliminate our contribution to the gradual accumulation of substances and compounds formed by society 3. ...degradation through physical intervention 4. ...and people are not subject to conditions that structurally hinder them in meeting their basic needs.

Sustainability principles

5. ...eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes, and...
The municipality and the housing cooperatives as well as numerous companies in the Eindhoven region have been trained in following the ‘The Natural Step’ philosophy.

Housing cooperatives in Eindhoven

The housing cooperatives have used The Natural Step to formulate a vision in relation to sustainability:

**Sustainable Energy** – All the energy needed in the Brainport region is generated sustainably, and wherever possible locally. The revenues from overproduction contribute to the sustainable development of housing in the region.

**Responsible transport** – Transport in the region has become independent of fossil fuels. The number of transport movements has been reduced by the introduction of flexible working, and the number of vehicles used has been reduced by sharing and alternative forms of transport.

**Collective awareness** – All those involved take shared responsibility for the living environment, and we are proud of what we can achieve together. We share our knowledge and celebrate our successes together.

**‘Living in a Lab’** – We are known for our innovative solutions that we develop (and have developed) together with all those involved, and we apply them flexibly to meet the needs of our citizens and future generations.

**Closed loop** – All our materials and buildings come from and/or are returned to healthy closed cycles. Our waste is given a new life as building materials.

**Long Lifetime** – Our buildings and the people who live in them and use them have a long lifetime through the creation of a healthy living environment and attractive, flexible living conditions.

**We look further** – We are passionate about the conditions behind the products and services that we provide. As a result we make a positive contribution to living conditions in other places, and we defend the rights of those who cannot do so for themselves.

**Natural city** – We maintain ecosystems, and wherever possible we restore systems to their natural balance. We help others in making responsible choices and in linking nature and the built environment.

**Costs become benefits** – We succeed in reducing the cost of living and in this way in creating the freedom to meet the basic needs (of life).

The innovation network in the Eindhoven region in relation to energy-neutrality

The Eindhoven region is well known for its innovative strength in terms of technology and design. An impression of the region’s innovation network in the energy-neutrality domain is shown on page 10.

The network as shown is far from complete. Subsidy regulations are constantly changing, driving the creation of new links. A lot of the networks at present still focus strongly on the subsidy regulations. Networks that are really dedicated to implementing the energy transition are present to a limited extent.

Because the money flows (both subsidies and business results) do not overlap, there are some gaps in the network that are serious obstacles to the flow of innovations from ideas to implementation and export.

There is a lot of talk about projects, but our limited network study shows that there is a so-called ‘loosely coupled network’. This is characteristic of a strongly innovative, knowledge-study network. To put the energy transition into practice, there is a need for an additional structure with a stronger focus on implementation. This is a network structure with more links between the various involved players, which results in a much more knowledge-study structure.
The most important trends, opportunities and challenges for Eindhoven Energy neutral were identified in a preliminary study carried out by desk research and a large number of interviews with experts of varying backgrounds.

Urbanisation

With a population of around 220,000, Eindhoven is located in one of the largest segments of the urban areas: the park cities [IIASA, 2013].

• They have a relatively low population density.
• There is a relatively large proportion of ‘green’ space.
• There are good links by road with the centre, which results in high use of cars and relatively low use of public transport.
• There is a relatively large proportion of low buildings, and the heat/cold ratio is less favourable (5:1) than in cities with more high buildings (1:1).

These factors mean that the park cities demand a specific approach in relation to energy-neutrality. In addition, the expectation is that the number of park cities with populations of less than 200,000 will increase significantly in the coming 40 years [IIASA, 2013]. This creates the opportunity for Eindhoven to play a role in the regional sustainability economy.

More autonomy and mass individualisation

Technology development has led to increasing individualisation and autonomy in society. People have tremendous freedom in terms of communication and travel, the choice of available products and services, and the way they lead their lives (education, hobbies, children, work and where they live). This high level of individualisation makes effective top down management difficult.

In addition, there has been a trend in recent decades away from the welfare state and towards more individual responsibility, in which people ‘look after themselves’, with a less prominent role for government in every aspect of their lives. Citizens will increasingly have to take more responsibility for themselves, for their families and for the environment in which they live. This applies to their economic situation, but also to the quality of life in their environment and the related sustainability decisions.

However, according to experts the level of independent thinking, decision-making, action and initiative by citizens is low. Around half of the citizens are not aware of the impact of our current energy approach or regard sustainability with suspicion.

This situation represents an opportunity for a neighbourhood approach to achieve sustainability. This will allow cooperation between private initiatives and initiatives by housing cooperatives (and also between housing cooperatives) to create synergies in the local infrastructure. These investments can be realised much more quickly if they are initiated jointly by a large part of the neighbourhood, private citizens and housing cooperatives working together. A number of the success factors for approaches of this kind have been identified, forming the basis for effective and efficient implementation.

Low involvement in ‘Energy’

For most people, energy is currently a low involvement topic [Midden, 2013], and they are not consciously involved in energy issues. Most people only look once a year at their energy bill, and have little awareness of where energy is used and what the consequences are if we continue using energy in the same way as we do at present. This is not so surprising, because the average citizen of the Netherlands has never had to worry about energy in the past 60 years. It has always been available, and simply comes into the home through the meter cabinet. It was something you didn’t need to think about.

But there are also situations in which this low involvement can suddenly change, as for example Shell found out in the Brent Spar, where the aspect of environment quickly gained a much higher level of emotional attention. This shows how sustainability and energy can suddenly become the subjects of much stronger involvement [Agterberg, 2013].

From individual ownership to shared use

The average age of people living in housing cooperative homes is decreasing, and the new generations have a different view of ownership [Trend Rede, 2014]. They are much more concerned with daily access to products and services, and less with possession. The ‘sharing economy’ is gaining support. For some this creates feelings of loss of control. But in the past there have been positive effects when government limited itself to defining some rules and then left things to individuals, as
Surface area usage for energy generation is increasing

Sustainable energy in the future will require more localised, through subsidies and regulation, solutions and services, but the long economic payback times make these relatively unattractive. This partly explains the sustainable energy transition more difficult there. Sustainable energy means use has to be made of local conditions. Solutions will differ, due to local factors like population density, the presence of other industries at the start of their industrial development, and use must be

A surplus of technology

As the authors of TrendRede 2014 note: there is a huge surplus of available technologies. Choosing the right technology is a complex and non-transparent matter. Based on the idea of ‘energy’ (a kind of quality mark for energy), two clusters can be distinguished:

- Energy media with a high exergetic value. This energy media, such as electricity, gas or petrol, can be transported relatively easily and can be used in many different ways.
- Energy media with a low exergetic value. This energy media, such as cold water (relative to the environmental temperature) can almost only be used for heating and cooling applications. This form of energy cannot be converted into other energy media — for example — electricity, or otherwise this can only be done with a strong energy waste. Energy media with a high exergetic value can very easily be converted into energy media with a low exergetic value. But conversion in the opposite direction is much more difficult.

The table below shows the sustainable energy technologies, subdivided by the energy level of the energy medium used. A more detailed version can be found in Appendix C.

The huge range of possible technologies, each with its own strengths and weaknesses, and some of them insufficiently tested in practice, presents a complex and non-transparent picture. But of course this is a fairly normal situation, that also existed in other industries at the start of their industrial development.

This makes it important, in the choices that will have to be made in the coming years, that the economic payback time is relatively short so new investments can quickly be made in better technologies. The robustness of the technology (does it work when we want it to?) is also an attention point. And finally, if the investments to be made are far reaching and have long economic payback times, the choice of the energy structure should be future-proof so that technology improvements cannot be incorporated without having to write-off earlier investments.

Sustainable energy technologies

<table>
<thead>
<tr>
<th>Sustainable technology (link)</th>
<th>Characteristics</th>
<th>Energy generation</th>
<th>Energy-saving</th>
<th>Energy storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-extractive</td>
<td>Easy to transport, can physically be widely expanded</td>
<td>From: Wind, Solar (PV), Biomass, Geothermal, Hydro</td>
<td>Behaviour, Demand side management, Flywheels</td>
<td>Pumped water storage (dark)</td>
</tr>
<tr>
<td>Low-extractive</td>
<td>Strong locational, generation and use is located near to each other</td>
<td>From: Electricity, heat from geothermal, Solar (solar collectors), Waste heat from industry or household use</td>
<td>Behaviour, Insulation</td>
<td>Water in an insulated environment, such as, a building, or a hot insulated ground water layer</td>
</tr>
</tbody>
</table>
Together towards Eindhoven energy-neutral in the built environment in 2045

In 2045, the built environment in Eindhoven is totally energy-neutral. Based on the preliminary study of the trends, opportunities and challenges, a number of elements that are necessary to realise the objectives can be formulated explicitly. Five key elements in the Eindhoven energy-neutral 2045 vision have been defined in a workshop with the involved executive councillors Schuurs and Helms of the Municipality of Eindhoven and management executive Eggertsmann of the ‘Woonbedrijf’ housing cooperative. These are mainly instrumental in the way in which Eindhoven intends to become energy-neutral in the built environment. This means these values need to be implemented by around 2015.

Value system

Towards 2045 Eindhoven has developed a good value system. All citizens and other involved parties have become aware of what sustainability means, as well as of their own role in it. The individual actions that were broadly accepted in the early years of the implementation of the energy-neutral Eindhoven have grown into collective actions, in which the different stakeholders work together to create sustainable solutions. A new ecosystem has also been developed, in which the wider idea of value is applied. In this ecosystem, different organisations work together to carry out sustainable value. People are also aware of the consequences of their choices and behaviour. One example of this is that more emphasis is placed on the use of goods, rather than on their possession. As a result of the emphasis on real value, Eindhoven has developed a good reputation with a fear of change, it is important that attention is also given to developing and implementing new business models that promote and encourage sustainability. There is a clear awareness that the transition to sustainable solutions is not only a matter of technology, but also requires attention for an honest distribution of value that promotes and supports sustainable solutions. The smart choices made in the pilots running in the living labs promote fast and efficient innovation, further supporting sustainability. The involvement of innovative companies in the pilots creates economic activity in the region, with new sustainable technology that is well matched to the needs of end-users. The strengths of Eindhoven as a city of design and technology are actively combined.

Innovation & learning

The transition to sustainable energy-neutrality does not follow a linear route but is a learning process. In Eindhoven there are collaborative initiatives in innovation and learning by all the involved parties: citizens, public and private organisations and knowledge institutes. Eindhoven leads the way in the application of innovations in testbeds and living labs for sustainable solutions. Through this leadership role Eindhoven gains the status of demonstrator city at EU level. The smart choices made in the pilots running in the living labs promote fast and efficient learning, further supporting sustainability. The involvement of innovative companies in the pilots creates economic activity in the region, with new sustainable technology that is well matched to the needs of end-users. The strengths of Eindhoven as a city of design and technology are actively combined.

Decisions

The decisions taken in Eindhoven are based on considerations of all the relevant factors. These decisions are taken at the right level by all the involved parties. A broadly based approach has been taken for this decision-making process, taking into account all the relevant economic, ecological, social and other aspects. Complementarity of options is actively sought (‘synergy loops’). The process also involves collaboration across boundaries, with attention for an honest distribution of value that promotes and supports sustainable solutions. For a good cross-boundary decision-making process, individual roles and their distribution are continuously monitored and reviewed. Responsibilities for choices are shared between citizens, companies, knowledge institutes and government.

Vision

Together towards Eindhoven energy-neutral in 2045

In 2045 Eindhoven takes its responsibilities to achieve the defined sustainability targets. This will require an increased influence if decisions need to be taken above the municipal or regional level. Particularly when Eindhoven has achieved demonstrator city status, Eindhoven will be able to ensure that sufficient attention is given to important issues at national or EU level.
Visualisation of the desired scenario

There is broad agreement on where Eindhoven stands in relation to energy. Eindhoven is energy-neutral by 2045, but ideally before that for the built environment. In other words, fossil fuels are no longer used, and have been replaced entirely by renewable (sustainable) energy sources such as wind, solar, hydro and biomass.

Awareness

Even though there is still a media debate about the impact of using fossil fuels, there is a clear consensus on the effects of global warming: extreme climatic conditions, rising sea levels and acidification of the oceans, extinction of animal species, retreating glaciers and melting icecaps, declining food production and drinking water reserves, and greater chances of wars due to increasing scarcity. Currently only a small group of people are aware of these threats and are actually working to avoid the worst-case scenarios. These effects are visualised in the adjoining figure by someone who is working hard with all kinds of apps to monitor and reduce his energy consumption. But unfortunately there are still people who have little awareness of energy-neutrality and sustainability, and who have certainly not transformed these into sustainable behaviour. They are shown at the right next to the path.

The first autonomous choices: behaviour, insulation and solar energy

The first step towards an energy-neutral Eindhoven is changing behaviour, for example by not leaving heating/cooling on if there is no-one at home, or by putting on the washing machine only when full. This accounts for a large part of the energy needs in the built environment. The focus at present is on replacing the use of fossil gas by a more sustainable solution, for which solar and wind power alone will be absolutely insufficient.

Thinking ahead to make infrastructural choices

Heating and cooling systems require suitable transport and storage media. In contrast to electricity, the generation, storage and use of energy need to be located close together. Fundamental local infrastructural choices therefore need to be made, and these will require major investments. All the available technical solutions have their own advantages and disadvantages. Scientists and researchers are urgently seeking for new and better technology. This means there is a significant chance of making investments that will quickly become obsolete as a result of new technologies. The timing of fundamental choices is therefore very important. The importance of a neighbourhood approach

Sustainable energy measures at neighbourhood level, whether in terms of behaviour, the purchase of solar panels, and especially heating and cooling systems, will be much more effective and will more quickly deliver a positive return on investment if citizens, business and industry, housing cooperatives and the municipality all act together at neighbourhod level. This goes hand in hand with changes in society, through which government is withdrawing and participation by citizens is increasing. Sustainable energy is not just an economic issue, focusing on the ‘homo economicus’ in us, but is very much a social issue, addressing the limitations of our common pool resources, requiring the ‘homo socialis’ in us. Social cohesion at neighbourhod level has to be strengthened, and people need to come forward to take the initiative and help take sustainability in the neighbourhoods to the next level. The biggest challenge for all parties in Eindhoven energy-neutral 2045 is to create new forms of dialogue, decision-making and collaboration.

The energy transition: acting on several fronts at the same time

The energy transition means acting on several fronts at the same time. This is shown at the bottom right in the figure by the network of tubes, wires and social relationships indicated by the maps. All the maps show possibilities and impossibilities. A decision on one of the maps can imply a decision on one of the other, either making that decision redundant or implicitly taking it. Smart, integrated decisions on multiple maps lead to an efficient and effective sustainable energy system for both electricity and heat/cooling. Visualising decisions and their impact on the different maps provides insight into which decisions can now already be taken, and in which the biggest learning effects can be found.

The importance of a neighbourhood approach

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Value drivers of energy systems

To understand the most important factors on which the decisions relating to energy will be based, an investigation has been carried out into the value drivers in energy systems.

The value drivers are important factors in taking decisions relating to the use or purchase of a system, service or product. Which value drivers are relevant for the (future) users, owners or other stakeholders of energy systems has been determined by means of interviews and desk research. This has resulted in a list of eight value drivers (see also page 20):

- Efficiency in the reduction of fossil energy
- Economic potential
- Social value
- Health & comfort
- Architecture
- Economic value
- Robustness
- Autonomy

The system does not create any health problems (unhealthy particulate concentrations, high CO₂ levels etc.), problems (unhealthy particulate concentrations, high CO₂ levels etc.), problems (unhealthy particulate concentrations, high CO₂ levels etc.), but also to identify underlying needs and for the positioning of energy neutrality.

For a more elaborate explanation of value drivers, the value ladder, user segments and how they impact decisions, please refer to appendix A.

Transition to energy-neutrality

Value drivers of energy systems

Value ladder energy

<table>
<thead>
<tr>
<th>Value driver</th>
<th>End- and instrumental values</th>
<th>Consequences &amp; advantages</th>
<th>Value ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency reduction fossil fuels</td>
<td>Sustainable society</td>
<td>Better for the environment and people on earth</td>
<td>Wisdom</td>
</tr>
<tr>
<td>Economic value</td>
<td>Making home and environment more pleasant</td>
<td>Social recognition</td>
<td>A world without war and conflict</td>
</tr>
<tr>
<td>Social value</td>
<td>Sustainable behaviour, visible to others</td>
<td>Healthy and comfortable life</td>
<td>Freedom (independence)</td>
</tr>
<tr>
<td>Health &amp; comfort</td>
<td>Sustainable solutions available in case of energy shortage</td>
<td>Healthy and sustainable society</td>
<td>No worries about economic situation</td>
</tr>
<tr>
<td>Robustness</td>
<td>Affordable solutions available when I need it</td>
<td>No worries about health</td>
<td>No worries about food and energy</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Take more decision-making energy</td>
<td>Energy available</td>
<td></td>
</tr>
</tbody>
</table>

It is important for the roadmap that different positioning strategies are included, to ensure maximum support for achieving energy savings and sustainable solutions.
The evolution of value drivers

The ‘value’ of a value driver changes over time. Four phases can be distinguished, as shown below (see also the figure below):

- Before I: The expected system users or decision-makers are often not aware of a specific need. This means no direct survey can be carried out of their preferences or wishes. However, it is possible to identify their needs indirectly, for example through the deeper values. There is good reason to believe that ‘energy-neutrality and sustainability’ is not yet recognised as an important need by most of the citizens of Eindhoven.

- Between I and II: The decision-maker now recognises the need for and the importance of this value driver. The potential effect of the value driver is high enough to make at least a number of early adopters take action. Those who are actively involved in sustainability recognise that there are already numerous opportunities, but that it is not clear what the best choices for Eindhoven are.

- Between II and III: In this phase the main options are clear, and the alternatives can be compared. The value drivers are known, and are included in most decision-making processes.

- After III: The value driver has turned into a ‘dissatisfier’: if the system fails to meet the requirements, purchasing or using this system will not even be considered. Choices at this stage are made on the basis of brand or reputation and price.

Development of the value drivers for energy

To gain an understanding of the development of the value drivers for energy systems over the lifetime of the roadmap, estimates of the development of the value drivers for the coming decades were made in two groups in the workshop with experts. These were then integrated into a single timeline (see page 19).

Subsequently, a brief explanation of the estimates that were made will be given for each of the value drivers. A detailed description of this process can be found in Appendix A.

Evolution of value drivers

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- After III: The value driver has turned into a ‘dissatisfier’: if the system fails to meet the requirements, purchasing or using this system will not even be considered. Choices at this stage are made on the basis of brand or reputation and price.
There is still little awareness among citizens that energy neutrality and sustainable behaviour are essential to maintain the health and safety of the living environment in the longer term. Development of these value drivers is necessary to avoid a very slow transition to a sustainable society, because the only other relevant driver will then be cost saving. This is an uphill battle against grey energy, which for the moment is still very cheap. As well as that, economic arguments provide little motivation for most citizens.

An ecological disaster in the ecosystem could greatly accelerate these developments. Citizens will then call on the government to act quickly and take measures to limit the damage.

A healthy and comfortable living environment is part of welfare. Climate control has to be an integrated element in the design of a (passive) house or building, but also in improving existing houses and buildings. (Day)light is also an important factor. What makes health and comfort difficult to deal with is the fact that few people are aware of the effects on their health and welfare, partly because these effects cannot immediately be noticed.

It is a reasonable expectation that in 10 years from now sustainable technology will need to add ‘beauty’ to the landscape or a building, or otherwise it will have an unsightly (solar panels on a 1930s house, wind turbines in the landscape). The challenge is to use sustainable technology in a way that makes people experience their surroundings as an attractive place to live.

Efficiency of the reduction of fossil energy and contribution to sustainability

A coordinated transition from grey to green energy is important to ensure that the use of grey energy declines, but that this form of energy still remains available as long as necessary in the most sustainable and flexible form possible.

Research findings show that behaviour will only change when it becomes clear how economically citizens use energy relative to their direct neighbours [Midden and Laskey 2013]. This means technology has an important role in providing feedback on individuals’ own behaviour, or on their behaviour relative to their direct neighbours. This feedback should be provided in a very quick and user-friendly way by the use of all kinds of equipment and sensors (the ‘internet of things’) and the availability of open data.

As well as insulation, sustainable behaviour is an important tool for energy-saving. ‘Social technology’ can be of great value to Eindhoven in achieving its energy-neutrality objectives.

Autonomy

A good range of services and simple citizen–service user-interfaces will contribute to freedom of choice in sustainable energy systems, both in the decision-making process and in the use of those systems.

Economic potential

It may be less relevant for citizens, but for other stakeholders economic potential is an important factor. This applies especially to the possibility of developing and exporting knowledge, products and services, and thereby also to create sustainable jobs in industry.

The coming years will be decisive for whether the Eindhoven region will need to buy-in many sustainable solutions, which means sustainability will lead to a negative cash flow out of the region, or if many people in Eindhoven will earn sustainable jobs in industry. (Day)light is also an important factor. What makes health and comfort difficult to deal with is the fact that few people are aware of the effects on their health and welfare, partly because these effects cannot immediately be noticed.

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The different layers of the energy system that require different knowledge.

Intelligent Lighting Institute

An energy transition model for Eindhoven

The preliminary study shows that the energy domain is a more complex matter than the earlier roadmaps that were made for public lighting or education. This complexity is due mainly to the many different information layers involved, each with its own specific knowledge and network of experts. To allow integrated and optimum decisions to be reached and implemented efficiently, the required information needs to be exchanged among the different layers. The different layers that emerged from the preliminary study are shown in the figure at the left. Each layer is actually a map of Eindhoven which shows a specific aspect of energy systems.

Relationship between value drivers and the energy transition model

Different green energy systems may be chosen locally in the different neighbourhoods in Eindhoven, because of local conditions and prerequisites. Different scenarios will be defined for all these neighbourhoods (with different combinations of layers), in answer to the specific local energy situations (local supply and demand). The involved local stakeholders will give different weighting to the different value drivers, depending on their personal values and prerequisites (such as subject knowledge and financial strength). The possible scenarios for solutions will then be assessed on their locally weighted scores for the value drivers. This process will need to be repeated on a yearly basis and the plans updated, because of the rapid developments in the energy field.
A system transition needs a growth path to reach a situation in which ultimately all energy is sustainable. There are a few well-known growth models. The best known is the ‘exponential growth curve’. Less well known, but more relevant for the energy transition, is the ‘hyperbolic growth curve’.

The part of the energy transition that requires the least infrastructural change has an exponential growth curve, for example the installation of solar panels. Another part of the energy transition, in contrast, requires significant changes in the infrastructure – this has a typical hyperbolic growth curve. For the roadmap and the options to reach the desired scenario for 2045, it is important to understand these models to allow the right steps to be taken and to anticipate the possible growth scenarios.

Exponential growth curve

In a situation with maximum freedom of decision-making, each citizen takes an individual decision and if the available solution really is better there will in general be a typical exponential growth curve. A second characteristic of exponential growth is that as soon as a better solution is available this will over time be substituted for the original solution. Solar panels, insulating houses and installing high-efficiency boilers are typical examples of exponential growth models of this kind.

Hyperbolic growth curve

If as well as better quality the (finally expected) number of citizens choosing the better solution is also taken into account, the growth curve will then change. If few citizens take part right at the beginning, this may be a reason for other citizens to ‘wait and see’. But as soon as a tipping point is reached in the number of participants, there is suddenly a big surge in interest. This means that at the beginning the hyperbolic growth curve is slower than the exponential curve, but once the tipping point is reached the hyperbolic curve is faster. As the rate of change in the infrastructure increases, larger numbers of citizens have to decide to take part to allow sufficient critical mass to be reached: if the required number becomes too large, and it takes too long before the tipping point is reached, the economic returns of the new infrastructure for investors will be poor and the risks will be higher.

A characteristics of hyperbolic growth curves is that if once the infrastructure has been institutionalised, it is very difficult for future better solutions requiring new infrastructure to once again reach the tipping point. There is a danger of (local) monopoly positions of the owners of the infrastructure, which is an undesired effect.

Differences between the hyperbolic and exponential growth curve

For a more elaborate explanation, see adjoining page (28).

System transition from grey to green energy

The difference between hyperbolic and exponential growth lies in the fact that the attractiveness of a proposition depends on the number of individuals who have already opted for, or will opt for, the proposition. For example: if you’re the only person with a mobile phone, nobody else will be interested in buying one. But if everybody you know has one, it’s a lot more attractive for them to buy one themselves.

The complexity of the decisions is linked to the number of layers that have to be taken into account in a transition, and ultimately the number of homes and buildings that are involved in the transition. There is a good chance that if the complexity becomes too high, a point will be reached at which government will enforce the energy transition. In this situation, government in effect disables the further progress of the hyperbolic growth model. Following the roadmap, the way in which this complexity can be taken into account in the implementation process will be considered in the second phase of the project [Eijgen & Winkler, 1987].
Eindhoven energy-neutral 2045 roadmap

The vision and the desired future scenario for Eindhoven energy-neutral 2045 have served as an inspiration in studying the possible ways in which energy-neutrality can be achieved. The desired scenario contains a number of elements of different kinds (building further on the layers shown earlier in the energy transition model), all of which need to be tackled together on the way towards energy-neutrality. It has therefore been decided to include these different aspects in the roadmap.

In preparation for the roadmap, a number of partial scenarios taken from the desired future scenario were developed in the expert workshop, together with the analysis of the value drivers and the transition model. Four of these partial scenarios in particular were considered:

• From a state of low awareness to sustainable behaviour: the challenge of motivating citizens to adopt sustainable behaviour and to invest in sustainability.
• Small, local systems: neighbourhoods or groups of houses with a shared infrastructure, especially for heating/cooling.
• The all-electric house: an extremely well-insulated house that generates all the required electricity and heating/cooling to provide a comfortable living and working environment.
• Eindhoven heating grid: a heating grid running through the city as backbone, through which all heating and cooling demand is linked.

The detailed results of this workshop are shown in Appendix B.

All information gained from the desk research, interviews with experts and workshops is clustered and summarised in three main categories in the roadmap.

**Sustainable behaviour**
How can we make all the citizens of Eindhoven aware of their behaviour in relation to sustainable energy and its consequences? And how can we then actually make them change their behaviour to save energy and maximise use of sustainable solutions? Two routes to achieve this are developed further:

• Creating awareness
• Persuasive technology

**Sustainable technology**
How are we going to make choices out of all the available technology solutions? Which infrastructure options will be available in the near future, and how can we set up the transition to sustainability over time? The focus is on the built environment (especially housing). Two routes to achieve this are developed further:

• Electrical energy (high exergetic value)
• Heating/cooling facilities (low exergetic value)

**Sustainable organisation**
How can we set up the organisation that will lead to collaboration between all the relevant parties to achieve the goal of energy neutrality? Because the technology is not yet mature, and new business models are needed, the learning process and setting up of testbeds are also important aspects. Two routes to achieve this are developed further:

• Public-private partnerships at strategic, tactical and operational levels
• An integral innovation process, from ideas through experiments and Living Labs to roll-out.

The complete roadmap is first shown on the following pages, after which this is further explained for each of the routes referred to above.
Roadmap Eindhoven Energy-Neutral 2045 - energy in the built environment

In 2045, the built environment in Eindhoven is totally energy neutral. A number of elements are necessary to realise the objective:

- In 2045, Eindhoven will have a good value system, linked to a strong understanding of the meaning and underlying principles of sustainability.
- In 2045, Eindhoven focuses mainly on ‘just doing’ it, not just talking, but actual implementation.
- In 2045, Eindhoven collaborates in innovation and learning with all the involved parties: citizens, public and private organisations and knowledge institutes.
- In 2045, Eindhoven takes the right decisions, based on overall assessments at the right level with all those involved.
- In 2045, Eindhoven takes responsibility and increases its influence where necessary to support the sustainability targets.

Eindhoven in 2045
Creating awareness

An important element on the road to full energy-neutrality in Eindhoven is creating awareness among all the citizens. As a first step, it is important to investigate which positioning will lead to the highest level of involvement among citizens. It is not yet sufficiently known how many citizens are interested in the value that sustainability represents. A lot of propositions are offered as cost savings, but people often do not find this to be a deep-rooted value driver (see also Appendix A).

A number of studies show that creating awareness requires a social approach. Technology alone is not enough. A neighbourhood-based approach has therefore been chosen for the roadmap, with the active involvement of citizens. The first step is to make a roadmap for each neighbourhood, showing all the initiatives and options for both individuals and housing cooperatives, so plans can be made in line with The Natural Step. In this process it is important that a range of intervention tools are developed to ensure that the great diversity of people, with different wishes, motives and abilities, all become aware of and take part in the dialogue. To show the real costs of energy (including the hidden costs of grey energy), it is important to make these clear (using open data). This will be done in a convenient way and reach influence large groups of people.

Important steps in the roadmap are to consider how awareness can be achieved through social conformity, open data is needed to make it possible to compare credits for energy (comparable with other districts). However it is important to create customised solutions that take into account the differences between people, their behaviour, the values they strive for and the underlying technology. This can be done jointly wherever possible, but it is also necessary to meet individual needs to win the support of everyone involved. This also means that a number of possible options need to be provided, preferably in the form of a modular system in which people can make their own choices. Depending on their involvement this can be a more or less passive process. For persuasive systems that respond to the behavioural change through social conformity, open data is needed to make it possible to compare energy consumption amongst people while also fulfilling privacy requirements.

Persuasive technology

Persuasive technology can be used to change behaviour or influence the way choices are made. Because of the amount of technology that we have gathered around us and the way this technology is part of everything we do, it is also a convenient way to reach and influence large groups of people. However it is important to support the process of social conformity in complex situations of this kind, this is the most important tool to achieve change – nobody wants to be ‘left out’ and support the process of social conformity: in complex situations of this kind, this leverage is the most important tool to achieve change – nobody wants to be ‘left out’ and support the process of social conformity: in complex situations of this kind, this

Open data makes it possible to gain an understanding of which causes are socially accepted, and this will enable people to get feedback on their individual energy consumption and the possible savings they can make. This needs to be done on a real-time basis whenever domestic appliances are used (for example, the washing machine settings).

We expect systems of this kind to be available within a number of years. As soon as all domestic appliances are connected through ICT (‘the internet of things’), far-reaching insight into individual energy consumption will be possible, and users will have the freedom to decide where to save energy and avoid waste.

The final step in the roadmap is the expectation that as long as sustainable energy is not available in ample quantities, its use can be regulated by means of budgets, so that extra (unnecessary) consumption will be charged at extra cost, in a similar way to the present prepaid system used on mobile phones.

Towards sustainable behaviour

The first two routes under the title ‘Sustainable behaviour’ – Creating awareness and Persuasive technology – are not independent of each other. Persuasive technology can help in the awareness process, and as soon as awareness has been created people will also be more receptive to support that persuasive technology can offer.

Important steps in the roadmap are to consider how awareness can be achieved among all citizens by means of a neighbourhood approach. In the first stages of the energy transition, this will require careful selection of neighbourhoods in which the probability of success is high and where it is also possible to learn what the specific problems are on the road towards full energy neutrality. The need for a coordinated approach with the other routes of the roadmap for sustainable technology and a sustainable organisation is also clear.

In the implementation of the roadmap to a programme of projects, attention will need to be given explicitly to the behavioural change component. The specific characteristics of the different growth models, as indicated earlier, have to be taken into account to achieve a total transition in an effective way.
Sustainable technology

Electrical / high exergetic value

If we really want to give the citizens a central role in our efforts to achieve energy-neutrality, we will have to make sure that they understand the ‘why’, ‘where’ and ‘what’. Which choices do citizens really have at present? Real participation in sustainability requires transparency and simplicity. That is a challenge in itself, but is not impossible – for example it has been successfully achieved with complex products like smartphones, so why not in energy? Participation in sustainability has to be a deliberate choice. This requires the right motivation, which in turn means technology needs to be developed to give citizens a sense of purpose (a better world for the next generation), mastery (they can take the right decisions and see that they are properly implemented) and empowerment (they can take decisions for themselves and together with the people in their neighborhood). Part of this discussion is a business model involved. If citizens participate, then it is no more than logical that they have an understanding of the costs and of how the benefits and the risks are shared.

The economic picture for sustainable electrical energy is currently still a weak point. There are subsidies, but these are aimed particularly at the operational side of the equation. There are also things which are aimed directly at the infrastructure needed to create new businesses. If we really want to give the citizens a central role in our efforts to achieve energy-neutrality, we will have to make sure that they understand the ‘why’, ‘where’ and ‘what’. Which choices do citizens really have at present? Real participation in sustainability requires transparency and simplicity. That is a challenge in itself, but is not impossible – for example it has been successfully achieved with complex products like smartphones, so why not in energy? Participation in sustainability has to be a deliberate choice. This requires the right motivation, which in turn means technology needs to be developed to give citizens a sense of purpose (a better world for the next generation), mastery (they can take the right decisions and see that they are properly implemented) and empowerment (they can take decisions for themselves and together with the people in their neighborhood). Part of this discussion is a business model involved. If citizens participate, then it is no more than logical that they have an understanding of the costs and of how the benefits and the risks are shared.

The economic picture for sustainable electrical energy is currently still a weak point. There are subsidies, but these are aimed particularly at the operational side of the equation. There are also things which are aimed directly at the infrastructure needed to create new businesses.

### Electrical / high exergetic value

A study of the infrastructural impact at municipal level is relevant. Aspects that need to be considered in the scenarios include:

- **Locally available spaces and locations**
- **Consequences of electric cars, on both the supply and demand sides**
- **Economic attractiveness of wind versus solar power, both within the city limits and outside them**
- **Level of self-sufficiency that can be achieved**
- **Evaluating the consequences and likelihood of breakthroughs in areas like nuclear fusion, biofuels or photosynthesis, that could possibly make all local investments obsolete**

How can all these factors be managed? Perhaps by smart grids based on market mechanisms? And how can this be reconciled with the possibilities of top-down intervention in cases of disasters and unexpected scarcities? The whole understanding of how base and forecasts will need to be kept up-to-date to allow the right planning of the infrastructural investments over the coming years. Energy storage is still a big obstacle on the road to a totally green electricity supply, unless the unexpected breakthroughs referred to above occur and we de facto return to the old energy infrastructure with power stations, but now using green fuels.

### Heating / cooling / low exergetic value

Most of the heating and cooling needs are currently met in the grey energy area in buildings themselves, with the energy being provided by fuels with a high exergetic value such as gas and electricity. The freedom of citizens to take their own decisions is based on the ability to choose their energy suppliers and products. The energy proposition consists of a physical element (gas), which is a commodity, a perception element (‘green energy’) and a business element (‘in the next 10 years you will be charged a lower price each year’). A logical step is to start with technical measures such as insulation and ventilation. The main problem here is existing buildings, rather than new ones. Upgrading to B label is in many cases achievable, but reaching a higher energy label on the way towards A++ seems not be economically viable at this moment. The further development of ‘passive house’ technology and climate systems is also relevant.

A link with the owners’ layer and thereby also with the social layer is key to facilitate the roll-out of architectural energy saving solutions in the short term. A vital step in heating/cooling is the required infrastructure. The heating/cooling systems are highly localised, and in some cases even building-specific. Questions arising in this infrastructural study include: where will which technologies be chosen, and what are the potential technologies that may improve the social layer and the owners’ layer are involved.

At present sustainable heating/cooling technology is hardly economically viable at the level of individual homes. In case of low-rise buildings, due to an strong imbalance in the annual individual heating/cooling supply and demand, a minimum economy of scale (40-50 homes) is necessary to make these systems economically affordable. This presents a social challenge in gaining the support of each home owner involved. If this shared commitment is not achieved, the autonomy of citizens will be the first casualty, since the solutions have to be enforced by the public authorities and their partners. Here too infrastructural investments will need to be carefully timed, so that future innovations can still be connected to the system and their benefits gained. This will require continuous annual updating of the infrastructural plan, waiting for new investments when it is best to do so, and then making rapid investments when the right opportunities arise. Funding is not the main issue, but it may well prove to be a significant obstacle if it is not available when needed.
In the initial phase we will work together on the basis of personal trust, but it will gradually become clearer who takes which roles, and at a later stage which roles can become more formalised. Starting this discussion too soon usually leads to distrust and delays. According to the rules of group dynamics, the parties should first gain each other’s trust, then exchange information, jointly formulate the rules and standards. Of course this applies within the municipality itself, but if the reputation of Eindhoven in terms of sustainability extends beyond the city limits it can even have an influence at national or European level. This can allow Eindhoven to take the role of an industry shaper.

It is important to have objective models for energy performance so that the predicted energy savings from sustainability measures correspond to the results that are actually achieved, and can be translated into economic value. As soon as pilots like Areys are successful, upscaled can be considered within Eindhoven and certainly also outside it. It is important to create “showcases” that will help potential customers in understanding the benefits and the potential and lead to possible “exports”.

If we want to take citizen autonomy seriously we need to protect the citizens against the most serious forms of “opportunistic behaviour” by setting clear rules and standards. Of course this applies within the municipality itself, but if the reputation of Eindhoven in terms of sustainability extends beyond the city limits it can even have an influence at national or European level. This can allow Eindhoven to take the role of an industry shaper.
In the final phase of the project we worked on setting up the innovation programme to take the first concrete steps on the road to the desired scenario.

Need for innovation coordination

An important reason to set up a roadmap process for ‘Eindhoven energy-neutral 2045’ was the fact that although there are a lot of activities in this field in Eindhoven, there was nobody with an overview of what was happening and could check consistency. It was already clear at an early stage that as well as a roadmap there was also a need for a coordinating structure that would help in facilitating the implementation of the roadmap.

In fact three bottlenecks to energy-neutrality were identified, and workgroups are being set up to address each of these:

1. Lack of energy system knowledge
   - There are many parties offering only partial solutions to the energy solution. Products like insulation packages, solar panels, solar boilers and Thermal Energy Storage (TES) systems all need to be closely coordinated to provide the required energy at an acceptable kWh price. Even if systems are implemented on a step by step basis, it is good to know that the chance of future surprises leading to unexpected write-offs or extra investments, is as small as possible.

2. An underdeveloped market
   - Sustainability is not at the centre of interest of citizens. It is also difficult to approach citizens on the subject to raise its importance. There is a lot of talk about the quadruple helix of innovation (involving citizen, government, knowledge institutes and industry), but few good examples are available. The underdeveloped market also means that there is hardly any market-driven technology innovation other than on economic parameters such as payback time and total cost of ownership. In such a market it is almost impossible to build up a world-leading position, which means we are limited in our ability to regionally develop a globally competitive business. In this way the regional energy transition will become a costly exercise, and one that will bring little economic benefit to the region.

3. Infrastructure
   - Sustainable energy generation requires a lot of square meters land (1,000 times as much as for fossil fuels). Square meters are scarce in a city. Mobility, buildings, industry, infrastructure, water and greenery all fight for space and now local energy generation has to be added to this list. This requires a careful decision process. Moreover the sustainable energy solutions will have a big impact on the required infrastructure (all kinds of grids that will eventually need to be installed underground). Making the wrong choices could therefore cost the community a lot of money.
Innovation coordination structure

The innovation coordination structure as proposed above contains the following activity flows (grouped under the respective workgroups), which have the task of precisely addressing the above bottlenecks and ensuring that they are dealt with in a coordinated approach.

Three workgroups will be set up:

- Energy Infrastructure Workgroup
- Energy Transition Workgroup
- Energy Systems Workgroup

In the short term it has been decided to build the organisational setting bottom-up. This is to ensure that there are no negative effects on the activities which are already running, and are driven by the enthusiasm of the participants, but most of all to learn what works and what doesn’t during the project itself. In addition, this structure expands on the existing and growing semiformal network of individuals and organisations already committed to and involved in sustainability. All too often structures are defined that turn out to ‘throw the baby away with the bathwater’. We have chosen to build on the existing network, which means a flying start can be made with this platform. The formation of this platform is therefore a natural and logical next step for the existing network.

This is why it has been decided in the initial phase to recruit specific individuals to fulfil coordinating roles in the network and at operational level between the individual workgroups. Over time the structure will need to be strengthened, and there will be a need for an overall development team to provide broader and more in-depth coordination between the three workgroups. In the following section a further detailing and implementation of the three workgroups will be presented.
How

- Building networks with citizens and owners.
- Carefully monitoring and evaluating initiatives, translating the findings into knowledge and expertise, and passing this on to a network of transition "initiators".
- Building up and validating knowledge in relation to the value systems of citizens in relation to energy neutrality (which value drivers are dominant and why).
- Setting up and aligning an energy transition roadmap.
- Monitoring developments in comparable cities; participating in information exchange and knowledge transfer.
- Recruiting expertise to allow estimates to be made of the technical and social feasibility of aspects related to the transition.
- Basing the energy transition on The Natural Step (which value drivers are dominant and why?)
- Setting up a basic entity in which all the different initiatives can be brought together.
- Further development of the value-driver system.

Recent activities

These are activities that are already running, with coordination points within this workgroup for innovation.

- aqEnergie, Eikenburg de Roosten.
- Collaboration between the municipality and MorgenGevendEnergie.
- Collaboration agreement with WoolConnect.
- ‘Waanzinnige Woonwijk’: Citizens’ initiative in Eckart, Vaartbroek neighbourhoods.
- An Energy Team is already working in the Hanevoet, Ooievaarsnest and Kastelenplein neighbourhoods. Also involves climate teams.
- Eindhoven North etc. e.g. ‘Buro cement’, also working on a number of critical success factors for the energy transition, although not specifically on energy. Eckart, Vaartbroek neighbourhoods.
- Collective TES (Thermal Energy Storage) system in combination with extra insulation for Vredesplein new building project. An IEM (Energy Exploration Company) has also been set up.
- City of Eindhoven: Meerhoven biomass power plan. Sustainable production of hot water and electricity for thousands of homes, schools and others.
- Citizens’ collective in Meerhoven is working on a joint solar electricity roll-out. http://eindhoven.transitiontowns.nl/category/activiteiten/energy

Short-term activities

- First steps in the energy transition roadmap, which neighbourhoods will be approached first and how, alignment with the other workgroups.
- A clearer idea of how Eindhoven energy-neutral can be achieved.
- Knowledge exchange platform through which citizens of Eindhoven and professionals can communicate (e.g. WoolConnect, Co-Do).
- Setting up a basic entity in which all the different initiatives can be brought together.

Representation in the workgroup

- Housing cooperative, municipality (coordinators).
- Engaged private individuals.
- ESCOs (Energy Service Companies).
- Knowledge institutes in relation to social innovation.
- Contact role with the Energy Systems Workgroup.
- Setting up and aligning an energy transition roadmap.
- Recruiting expertise to allow estimates to be made of the technical and social feasibility of aspects related to the transition.
- Basing the energy transition on The Natural Step (which value drivers are dominant and why?)
- Setting up a basic entity in which all the different initiatives can be brought together.
- Further development of the value-driver system.

Energy Systems Workgroup

Aim

The Energy Systems Workgroup aims to kick the rapidly developing technology and the reality gap (from the point of view of the end users) from within the energy transition, which is a system approach based on the defined value drivers.

Numerous separate ‘components’ are available in the sustainable energy industry, such as solar panels, insulation and climatic control systems. For many decision-makers the list of possible options is very large and highly unclear. Unfortunately, there is little availability of sustainable energy solutions that approach the problem from a system perspective, even though there are increasing indications that this is what the ‘market’ really wants.

An energy system is a system that meets all kinds of energy needs as efficiently as possible (high energetic value, e.g. electricity or biogas, and low energetic value, e.g. heating and cooling) to achieve (over time) the highest possible energy neutrality.

Role

Systematically keeping up-to-date with the latest knowledge and market developments that can lead to potential business in energy systems. Comparing (benchmarking) of technological opportunities following a system approach based on the defined value drivers.

Providing information and making recommendations about potential business opportunities to Brainport Development, which has the task of initiating and facilitating business development in the region.

Starting-up the Living Lab experiments and focusing on the most promising technology options. These technology options can also be found in sources from outside the region, as long as they are relevant to ‘park city’ Eindhoven.

Identifying technology bottlenecks, analyzing their societal impact and bringing these to the attention of knowledge institutes, industry and subsidy providers.
• From the perspective of innovation: ensuring that the infrastructure supports and facilitates innovation in sustainability by enabling future social and technology innovations to be tested and implemented quickly and without the need for extra investments.

• From the perspective of governance: monitoring and structuring the progress and status of Eindhoven towards the energy transition. For each neighbourhood, city area and the city as a whole, indicating the current status in terms of energy saving behaviour, insulation, energy consumption and the relative proportions of grey and green energy.

**Role**

Facilitating the energy transition by designing a structure for the overall energy system of the Eindhoven region that links but also allocates the different parts of the energy systems (where will different energy technologies be used – e.g. bio energy, heat-distribution network, TES) in line with the interests of citizens and government.

Putting forward infrastructure designs to the municipality and to citizens, including the considerations on which the municipality can take decisions with respect to zoning plans and citizens can participate in the democratic decision-making process on infrastructure.

Developing and maintaining models to allow analysis and assessment of the current state-of-the-art of energy-neutrality at different levels of aggregation, such as the city, city area and neighbourhood. The models are based on Life Cycle Analysis, in other words they take into account not only the energy behaviour during use, but also production, installation, maintenance, service and decommissioning at end-of-life. Initial studies show that in the long term both the costs of

**Recent activities**

Current activities to be coordinated from this workgroup:

• Energy system concepts within the ESCO-VVB (Energy Service Companies-by and for citizens) project within the Aireywijk project and 4-5 neighbourhoods in Woonset Noord and/or Tongeplein in preparation.

• Collective TES (Thermal Energy Storage) system (e.g. Vredesplein).

• Biomass for neighbourhood hot water and electricity supply (Meerhoven).

**Short-term activities**

• Attracting subsidies that are in line with the aims of this workgroup.

• Setting up a first-generation energy systems roadmap, first step is to identify the technology options.

• Building up energy system expertise in the region.

• Where attractive options with regional business potential are identified, notifying Brainport Development about these as quickly as possible.

**How**

• Maintaining an energy system roadmap showing the evolution of future technology developments.

• Helping to set up and facilitate Living Lab experiments and capturing the learnings from them.

• Providing information through Brainport Development or directly to companies in the region, and supporting them in business developments related to sustainability.

• Recruiting expertise to allow estimated to be made of technical feasibility of aspects related to the transition.

• Annually aligning the energy system roadmap with the transition roadmap and the infrastructure roadmap.

**Representation in the workgroup**

• Brainport Development (coordinator).

• Knowledge institutes in relation to design, technology and social innovation.

• Coordinating function to the other workgroups.

• Contact role with the other workgroups.

**Aim**

The Energy Infrastructure Workgroup aims to translate the wishes of all those involved in the energy transition (citizens, owners, municipality, knowledge institutes and industry) into an urban energy infrastructure based on the existing and potential social and technical possibilities.

**Recent activities**

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• Annually aligning the energy system roadmap with the transition roadmap and the infrastructure roadmap.
energy consumption and the expected costs relating to CO2 emissions (see as example United States Environmental Protection Agency, www.epa.gov) are taken into account. The models make projections for the next 50 years. An interesting alternative is the use of ‘eco-cost models’ based on prevention, such as those developed at Delft University of Technology (Nogttaard, 2009). A good overview of all ‘eco-study’ models is given in [Broekhuizen, 2014]. Citizens and other stakeholders know what specific opportunities there are in their own neighbouringhoods, homes or buildings in relation to improvement of energy-neutrality, or what improvements may be under consideration for the future. The information for each location which is relevant for taking decisions in relation to the energy balance needs to be gathered and compiled, and presented to the community in an accessible and intuitively visualised form to facilitate the energy transition.

Each year this workgroup will actively encourage and support the other workgroups in updating the neighbourhood/city area/city roadmaps based on the latest technological developments and the changing needs of the community. Based on the results of this process, the infrastructure roadmap and the transition roadmaps are updated and aligned. Identifying gaps and making research recommendations, as well as recommendations for subsidies to the bodies and organisations providing them. Promoting participation in subsidised activities by the bodies and organisations providing them.

How

• Recent activities

<table>
<thead>
<tr>
<th>Activities to be pursued by this workgroup:</th>
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<tbody>
<tr>
<td>• ‘Zonnetas’ solar energy initiative launched in March 2013 at the WO (Eindhoven).</td>
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<tr>
<td>• RES potential map (<a href="http://atlas.sre.nl/wo/">http://atlas.sre.nl/wo/</a>).</td>
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<tr>
<td>• Residual heat map and heat distribution networks being developed (e.g. by province and SRE city/city- gion Eindhoven).</td>
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<tr>
<td>• Research into opportunities for geothermal energy (European collaboration)</td>
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<tr>
<td>• Fibre-optic roll-out.</td>
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<tr>
<td>• Research into SmartGrids electricity network (e.g. with TU/e, Alliander and Endinett).</td>
</tr>
</tbody>
</table>

Recent activities

- Obtaining subsidies that are in line with the aims of this workgroup.
- Starting / strengthening provision of information about the various knowledge layers (solar, wind, social cohesion, energy supply & demand etc.).
- Setting-up first-generation quantitative models, and based on these models identifying gaps in knowledge and promoting research to bridge these gaps.
- Setting-up a first-generation infrastructure roadmap together with the other workgroups.
- Making contact with other cities so that the models and approach will ultimately lead to a European model for urban energy systems.
- Defining an open data structure to store infrastructure information.
- Marketing and communication to create awareness in the municipality about the Energy infrastructure Workgroup and what it has to offer.

Horizon 2020

- The Horizon 2020 programme offers a number of opportunities for European projects in relation to energy and smart cities. Contact has already been established through the network operator Eurocities to contact cities that want to co-operate in these areas. Work is being done to prepare and submit a proposal for a project in which together with other cities a vision and roadmaps are being developed for a number of relevant energy-related themes. Based on these roadmaps, concrete collaboration projects can then be started that are aligned with the priorities of the respective cities. Work is also being done on a preliminary study of other potentially attractive options, so that the findings can be submitted in 2014 and 2015.
Word of thanks

This vision and roadmap for Eindhoven energy-neutral in the built environment 2045 was produced by Elke den Ouden and Ruud Gal van LightHouse, solution partner of the Intelligent Lighting Institute at the Eindhoven University of Technology, for and in partnership with vice-mayor Mary Ann Schreurs (Gemeente Eindhoven) en Marc Eggermont (Woonbedrijf) in collaboration with Joost Helms (municipal executive board member), Jeroen Lebon and Alfredo Verboom of the municipality of Eindhoven and Rob Bogaarts of Woonbedrijf.

The project would not have been possible without the support and cooperation of all those who provided input and contributed through interviews and workshops. We would like to sincerely thank all those who have contributed, and especially:

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- Joop Ketelaers, City of Eindhoven
- Jansen Labon, City of Eindhoven
- Mary Ann Schreurs, City of Eindhoven
- Alfredo Verboom, City of Eindhoven
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Appendices
Appendix A: Value drivers

To understand the most important factors on the basis of which decisions relating to energy are taken, an investigation has been carried out to find the value drivers of energy systems. The preliminary study identified a total of eight value drivers. A workshop with experts was then held to consider how these value drivers are likely to evolve over the lifetime of the roadmap. Finally the results, together with a number of interviews with experts, were used as input for the roadmap.

<table>
<thead>
<tr>
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<th>Robustness</th>
<th>Economic value</th>
<th>Social value</th>
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<td>Health &amp; comfort</td>
<td>Architectural value</td>
<td>Autonomy</td>
<td>Economic potential</td>
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Value drivers

A value driver is a characteristic of a value proposition that forms an important factor in taking decisions relating to the use or purchase of a system, service or product. This decision can be taken by a (future) user, owner or other stakeholder.

The possible value drivers in relation to energy systems (whether sustainable or not) were identified on the basis of interviews and desk research. This resulted in a total of eight value drivers:

- Efficiency in the reduction of fossil energy and contribution to sustainability and compliance with sustainability principles of The Natural Step
- Robustness
- Economic value
- Social value
- Health & comfort
- Architectural value
- Autonomy
- Economic potential

Value ladder

To get a better understanding of deeper value, it is helpful to connect the value drivers to higher values. The value drivers can be connected to psycholog-ical and social benefits and/or consequences, by constantly asking the question of why a value driver is important. Those psychological and social benefits and consequences may have multiple layers. Further questioning leads to personal final values or instrumental values. A final value gives an indication of a desired situation or outcome. An instrumental value gives an indication of the way that desired situation or outcome is achieved. Systematically investigating the identified value drivers results in a “value ladder” (see the figure below). This is a first indication, and needs to be

verified by market research. However this is only possible for value drivers with the associated conse-quences and values, which the customer is aware of. In the jargon: “which fits into his or her current socio-cultural context”. There is considerable doubt about whether this is already the case in relation to energy neutrality, because many people are not conscious about energy and sustainable energy.

A value ladder is very useful (1) in identifying the differences between individuals (not everybody is the same), but also (2) in identifying deeper needs, and (3) in positioning energy neutrality as a sustainable issue is how to position the idea of “sustainability” and energy-neutrality.

Here are two examples of user segments:

- I believe in “sustainable energy” because I don’t want my children and grandchildren to have to live in a world in which the climate is out of control, and in which people are fighting for energy that’s too soft.
- I believe in “sustainable energy” because it is profitable.

As an example of how these segments lead to differ-ent profiles, the objectives of the cost conscious user and the sustainability conscious user are worked out in more detail.

Value ladder energy


Sustainable-conscious users

These are people who take the predictions of climatologists seriously, and are deeply concerned about how the earth will respond to the increasing CO2 concentrations and temperature increase. They have translated these wishes into consequences for their families, including long-term health consequences. They see no autonomy important, believe in this phase, ‘coasting for someone else to solve the problem’ is not the most successful strategy. The analysis of trends, opportunities and challenges already showed that energy is basically regarded as a ‘low involve-ment’ topic. The estimate is therefore that a large group of people are at present not conscious of sustainability, but could become conscious of it in the future. It emerged in one of the groups during the roundtable discussions that this could happen in two different ways:

- By successfully implementing a strategy for awareness, value and behavioural change in relation to suicide; the earth looks like a model engendering among the majority of citizens
- A serious incident, possibly with a number of victims, caused undeniably by the lack of sustainability, by successfully implementing a strategy for awareness, value and behavioural change in relation to suicide; the earth looks like a model engendering among the majority of citizens

The World Health Organization currently estimates the number of deaths resulting from global warming and CO2 emissions at 140,000 per year [WHO, 2013]. But how many people really find this disturbing, or even know about it? Almost none.

In general, the transition to a sustainable society has three aspects:

- Towards sustainable built environment (this transition in the closed)
- Towards sustainable mobility and transport
- Towards a sustainable built environment (this transition is the closest)

This is another reason to strengthen the focus on sustainability and to make it the core of an awareness ‘topic’. The estimate is therefore that a large group of people are at present not conscious of sustainability, but could become conscious of it in the future. It emerged in one of the groups during the roundtable discussions that this could happen in two different ways:

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- A serious incident, possibly with a number of victims, caused undeniably by the lack of sustainability, by successfully implementing a strategy for awareness, value and behavioural change in relation to suicide; the earth looks like a model engendering among the majority of citizens

The cost-conscious users

These are people who take the predictions of climatologists seriously, and are deeply concerned about how the earth will respond to the increasing CO2 concentrations and temperature increase. They have translated these wishes into consequences for their families, including long-term health consequences. They see no autonomy important, believe in this phase, ‘coasting for someone else to solve the problem’ is not the most successful strategy. The analysis of trends, opportunities and challenges already showed that energy is basically regarded as a ‘low involve-ment’ topic. The estimate is therefore that a large group of people are at present not conscious of sustainability, but could become conscious of it in the future. It emerged in one of the groups during the roundtable discussions that this could happen in two different ways:

- By successfully implementing a strategy for awareness, value and behavioural change in relation to suicide; the earth looks like a model engendering among the majority of citizens
- A serious incident, possibly with a number of victims, caused undeniably by the lack of sustainability, by successfully implementing a strategy for awareness, value and behavioural change in relation to suicide; the earth looks like a model engendering among the majority of citizens

One of the challenges in the coming years will be to move some of those who currently have no awareness and are still in the “cost-driven” segment towards sustainability.”

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One of the challenges in the coming years will be to move some of those who currently have no awareness and are still in the “cost-driven” segment towards sustainability.”
The evolution of value drivers

The value of value drivers changes over time. Four phases can be distinguished in this process (see also the figure below):

Before I

The person or decision-maker for whom the system is intended is not aware of the need. In this phase there is no point in asking questions. The usual radar form of content driven innovation also does not take place on the basis of market research.

Between I and II

The person and decision-maker now recognises the need for and the importance of this value driver. In any case, the performance that is offered on this value driver is high enough to make a number of persons take action. This is often a high period in which far too many technology alternatives are offered, and there are still a lot of shortcomings and uncertainties. Some early adopters may find that a challenge, but for many it will be frightening. Over time some alternatives will emerge (‘dominant designs’ takeback, 1956). Many of those who are active in the ‘sustainability field’ recognise that there are tremendous opportunities, and it is absolutely not yet clear what the preferred choice of Eindhoven will be and whether there is a chance to depend on the decisive emerging as the dominant design. This means that the sustainability of the choices to be made by the citizens, organisations and the municipal bodies in Eindhoven in relation to sustainability will preferably be those that have a high potential to become a dominant design, or otherwise to keep the switching barriers (the costs of choosing other technologies in the future) low.

Between II and III

A lot of things become clear in this phase; the main choices can be clearly identified and the value driver is well known, and is included in most decisions. Technological system solutions are compared.

After III

A value driver after III is really a sine qua non. If the value driver is not satisfied to a sufficient extent by a system, its purchase or use will not even be considered. The value driver is then a ‘disssatisfier’ – it is no longer distinguishing for the supplier, but a system is required at a minimum level is required [Kano, 1980]. Choices in general will no longer be those that have a high potential to become a dominant design, or otherwise to keep the switching barriers (the costs of choosing other technologies in the future) low.

Development of the value drivers for energy

To gain an understanding of the development of the value drivers for energy systems through the time-line of the roadmap, estimates were made in the workshop with experts in two groups of the development of the value drivers over the coming decades.

A detailed description of the development of each of the value drivers is given on the following pages.
needed. Large buildings often have a better balance between heating and cooling, and TES is more difficult due to the large building size.

In conclusion, there are a number of technical problems. The system penetrates deep into the ground, passing through all kinds of insulated layers, some of them containing drinking water. A well can also become blocked (3-5% chance), which means it needs to be carefully extracted and the hole in the deep insulating layer repaired, after which the well can still be filled. The costs of this operation are approximately €200,000 per well. A well is only economically viable if it serves several homes. Since 2013 Eindhoven University of Technology has operated one of Europe’s largest TES systems, with a capacity to heat around 500 homes. A total of 24 wells have now been drilled in the TES campus. Eindhoven has around 40,000 homes. Estimated calculations show that this means around 3,700 wells will be needed in Eindhoven, one every 180 meters. Finally, there is the problem that TES systems are regularly over- or under-dimensioned, as a result of which the efficiency and, especially, the economic payback time can be much less favourable than originally calculated. One advantage of multiple wells is that in case of suboptimal operation or other problems the wells can take over the heating/cooling function from each other and (or) can be taken out of service if necessary. This increases the chance of better economic performance and greater robustness.

New TES systems are being developed that use higher temperatures (60-90°) and also store in warm or cold water in large underground tanks (40 metres in diameter, 17 metres deep). A single well can be much less favourable than originally calculated. One advantage of multiple wells is that in case of suboptimal operation or other problems the wells can take over the heating/cooling function from each other and (or) can be taken out of service if necessary. This increases the chance of better economic performance and greater robustness.

In conclusion, these green energy systems are still far from highly robust, and until that is the case a totally green energy system for the built environment without the help of grey energy systems will still be needed to provide a continuing guarantee of robustness.

To investigate the economic value a detection needs to be made between new buildings and renovated existing buildings. The non-renewed building on a large scale is still relatively simple and an affordable cost. The biggest problems and the highest costs are in existing buildings, where the economic payback time is much longer due to both the economic and the low state of the local and national generation and is proven still critical a capital. Insulating homes to Energy Label ‘B’ will require a capital that is economically viable at present, but reaching Energy Label ‘A’ is not yet an economic proposition.

For this reason, a totally green energy system for the built environment without the help of grey energy systems will still be needed to provide a continuing guarantee of robustness. In conclusion, these green energy systems are still far from highly robust, and until that is the case a totally green energy system for the built environment without the help of grey energy systems will still be needed to provide a continuing guarantee of robustness.

To help initiate the transition to energy neutrality, subsidies and other favourable conditions are still very important if an adequate share of the public is to be fed back into the grid. The available subsidy schemes change regularly, as a result of which workers are faced with extra costs over and above what initially appeared to be an attractive cost-benefit analysis. This has also included subsidies, even though the economic proposition may at first look positive.

The large number of points of failure makes the economic viability of the transition to sustainable energy vulnerable. The new start-up of the energy transition in the Netherlands is closely linked to the fact that at national level the gas supply is an important foundation for the sustainable energy vulnerable. The slow start-up of the energy transition in the Netherlands is closely linked to the fact that at national level the gas supply is an important foundation for the competitive position of many of the country’s energy intensive industries. This leads to a lot of uncertainty and makes it difficult for investors to take the right decisions.

Too rapid phasing-out of the use of gas, preceded by a declining market value of the present fossil fuel suppliers, may lead to a crisis in the capital market. And as already indicated, grey fuels may be less necessary in the coming 20 years in terms of absolute volume, but they will still be needed as a valuable and flexible energy source. A coordinated grey-green transition is at least worth trying.

However the phasen times are such that a number of housing cooperatives are cautious in their planning for the energy transition, because the costs and the related uncertainty (for buyers) are in conflict with their core task of providing affordable housing for those with lower incomes.

Most housing cooperatives concentrate on insulated rooves and solar panels. Helping people to learn energy-saving behavior, offering sustainable wind energy facilities (which is economically much more attractive) and all kinds of heating/cooling solutions are at present not broadly supported by housing cooperatives (except for a few experiments).

It is important to consider the economic effects at two levels:

- Paybacks of the investments by savings on the operational costs, including energy bills
- As an investment, homes that have been insulated are worth more than those in which no investments have been made, even in existing buildings.

If a house is well insulated, a lot of attention should be given to ventilation. In a passive house climate control is integrated in the design. Comfort should also take this into account the necessity caused during the installation of the improvements, especially in existing buildings, both inside and outside the house. Even though this only lasts for a limited period over the whole lifetime of the house, at the time of taking a decision it is relatively close for many citizens, and therefore gets extra ‘negative’ significance.

It is important to consider the economic effects at two levels:

- Paybacks of the investments by savings on the operational costs, including energy bills
- As an investment, homes that have been insulated are worth more than those in which no investments have been made, even in existing buildings.

In other words an important driver for making choices in technology is whether the technology offers opportunities for feedback on people’s own behavior relative to their direct neighbors, which will result in social pressure leading to green behavior and green decisions. This social pressure will only work if there is also a certain degree of social cohesion in a neighborhood.

The Netherlands are convinced that in the case of each appliance in the home is connected to the Internet and has all kinds of sensors (‘the internet of things’). This enables very rapid feedback on your own behaviour. Open data will also allow different kinds of comparisons to be made. It is estimated that energy savings of more than 15% will be possible as a result of such behavior.

In 2015-2020 the average usage of 15% is expected as a result of investments in insulation, in view of the insulation level of the present housing stock. Of course the savings potential of a poorly insulated home is higher than that of one that is well insulated. This means that a saving of 15% — 40% as a result of sustained behavior and insulation measures for the built environment definitely makes it worthwhile for Eindhoven to invest in ‘social technology’.

Research shows that energy-saving behaviour of citizens is hardly influenced by a larger information (understanding of why we need to make society more sustainable), by economic benefits, by a better self-image of yourself as a citizen (‘green behavior’ box) or by social pressure. Behavior only changes when it becomes clear how economical citizens are in their use of energy relative to their direct neighbors.

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At present the architectural value (is the home and its environment attractive to live in?) is a neglected area. Either it is zero (a high-efficiency boiler and insulation are invisible), or it is considered to be ugly (solar panels on the roof, wind turbines in the landscape). Sustainable energy generation such as wind and solar power takes up a lot more land area than the use of fossil fuels. A city that wants to be energy-neutral with as much local energy generation as possible will have to go through a very significant transition in architectural terms. The challenge is then to see sustainable technologies as an attractive place to live. Ten years from now we can expect sustainable technologies that do not contribute any additional ‘beauty’ to the landscape to have little chance of success.

The challenge is then to use sustainable technology so that citizens see the environment as an attractive place to live. Ten years from now we can expect sustainable technologies that do not contribute any additional ‘beauty’ to the landscape to have little chance of success.

The past few decades have been a turbulent time in terms of social governance:

• Both government and major industries are struggling with the increasing complexity of society and the question of governance. Concepts like ‘autopoiesis’ (self-organisation) have been used, reflecting a government that has cut back on the tasks it performs.
• Increasing outsourcing in industry, and its equivalent in government, as well as increasing ‘privatisation’, have led to some efficiency improvements here and there – although not to the expected extent – but have also increased complexity.
• Many citizens are highly educated, they are well able to solve complex problems by themselves, and can create knowledge and production networks for the transition and its implementation. But there are others who need help, or are unable or unwilling to take decisions by themselves.

• The recent crises in the property market and in the banks, and the many ‘incidents’ in the ethical behaviour of large companies (for example:LinkedIn, ‘whistleblowing’ cases, measures that do not cure but instead make patients dependent on them for life, privacy violations, etc.) have made many citizens suspicious. Many product-market strategies of large companies are aimed at solving customers' problems, but only at making them dependent on products or services that simply increase complexity.

*• The management of the system must be simple for citizens.
• Citizens must be able to seek legal solutions without high lawyers' costs if things do not work in the way that was agreed.
• The management of the system must be able to be assigned at different levels of autonomy if citizens wish.

Unfortunately there are at present quite a number of sustainable technology solutions, for example TES systems which are only economically and technologically viable on a scale of at least 100-200 homes, or that are located far from the homes they serve. In fact the only sustainable energy solutions that can at present be made suitable for a high level of autonomy are insulants, sustainable behaviour using smart home appliance and solar & wind systems.

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Although possibly less relevant for some citizens, the ability of other stakeholders such as the municipality to export knowledge, products and services from the region can be a significant factor. Jobs are also important. The coming years will be decisive for whether the Eindhoven region will need to buy in many sustainable solutions, leading to a negative cash flow out of the region, or whether some citizens will earn their living in this way and bring money into the city, allowing other local investments to be made.

There are a number of important aspects of the chosen sustainability solutions that should act as enablers for a high level of autonomy of citizens:

• Economic (in terms of investment and maintenance, as well as possible risks): energy systems must be viable for individual home owners.
• The management of the system must be simple for citizens.
• Citizens must be able to seek legal solutions without high lawyers' costs if things do not work in the way that was agreed.
• The management of the system must be able to be assigned at different levels of autonomy if citizens wish.

Economic potential

Although possibly less relevant for some citizens, the ability of other stakeholders such as the municipality to export knowledge, products and services from the region can be a significant factor. Jobs are also important. The coming years will be decisive for whether the Eindhoven region will need to buy in many sustainable solutions, leading to a negative cash flow out of the region, or whether some citizens will earn their living in this way and bring money into the city, allowing other local investments to be made.
Appendix B: Scenarios for the roadmap

To get a better understanding of what is needed to achieve the goal of Eindhoven energy-neutral, a number of scenarios were reviewed in a series of workshop with experts. These scenarios are not mutually exclusive, but can be complementary. The scenarios are based on the most important elements that emerged in the preliminary study and the desired future scenario based on the vision.

- Scenario 1: From a state of low awareness to sustainable behaviour - the challenge of motivating citizens to adopt sustainable behaviour and to invest in sustainability.
- Scenario 2: Small, local systems - neighbourhoods or groups of houses with a shared infrastructure, especially for heating/cooling.
- Scenario 3: The all-electric house - an extremely well-insulated house that generates all the required electricity and heating/cooling to provide a comfortable living and working environment.
- Scenario 4: Eindhoven heating grid - a heating grid running through the city as backbone, through which all heating and cooling demand is linked.

The results of the workshop are shown on the following pages. The results are then used as input for the roadmap, together with a number of interviews with experts.
Scenario 1: From a state of low awareness to sustainable behaviour

The challenge to motivate citizens to adopt sustainable behaviour and to invest in sustainability.

Scenario 2: Small, local systems

Neighbourhoods and groups of homes that use a shared infrastructure, especially for heating and cooling.
Scenario 3: The All-Electric House

An extremely well-insulated house that generates all the required electricity and heating/cooling that it needs to live and work in comfort.

Scenario 4: Eindhoven heating grid

A heating grid that runs through the city like a backbone, linking supply and demand for all kinds of heating and cooling.
Appendix C: Technologies

Sustainable technology is still developing rapidly. On the one hand it is good to know how much innovative strength there is in this field. But on the other hand there is a good chance that any technology choices made now would be regretted in the future because much better solutions would then emerge.

A good overview of the technology options can be found in [Eneco, 2013]. It has been decided not to describe all the technology solutions. The source of this overview is [Eneco, 2013], and we also refer to this book for all the detailed descriptions.

The chapter 'Trends, opportunities and challenges' is subdivided into technology clusters (see also the table below right). The technology can be subdivided in different ways:

By function:
- Energy generation
- Energy saving
- Energy storage

In fact, the last function is a ‘dysfunction’ — in other words its task is to solve problems in the main function. For example: the fact that the sun doesn’t always shine when we would like it to means we need energy storage to deal with the difference between supply and demand.

By energy ‘quality’ of the secondary energy carrier:
- High exergetic value (Electricity / Gas / Fuel)
- Low exergetic value (Heat / Cold)

But the technology can be divided further by whether it is linked to a physical location:
- Within the Eindhoven region
- Outside the Eindhoven region

This appendix looks at the different technology clusters, and makes estimates of the scores of the different sustainable technologies on the value drivers. These scores are our own estimates based on the understanding gained in the preliminary study.

<table>
<thead>
<tr>
<th>Sustainable technology cluster</th>
<th>Characteristics</th>
<th>Energy- generation</th>
<th>Energy- saving</th>
<th>Energy storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-exergetic</td>
<td>Easy to transport, generation and use can physically be widely separated</td>
<td>From: Wind</td>
<td>Solar (PV)</td>
<td>Water (tidal, wave)</td>
</tr>
<tr>
<td></td>
<td>Behaviour</td>
<td>Domestic appliances</td>
<td>Pumped water storage (dams)</td>
<td>Compressed air</td>
</tr>
<tr>
<td>Low-exergetic</td>
<td>Strongly location-linked, generation and use must be located near to each other</td>
<td>From: Electricity, heat from geothermal layers, biogas or biogas oil</td>
<td>Solar (solar collector), waste heat from industry or household use</td>
<td>To: Insulation</td>
</tr>
<tr>
<td></td>
<td>Behaviour</td>
<td>Insulation</td>
<td>Water in an insulated environment, such as a natural vessel or a naturally insulated ground-water layer</td>
<td></td>
</tr>
</tbody>
</table>
Low exergetic sustainable energy solutions

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Technology</th>
<th>Applicable form of energy</th>
<th>Suitable location</th>
<th>Economic value</th>
<th>Social value</th>
<th>Health &amp; comfort</th>
<th>Architectural value</th>
<th>Sustainability value</th>
<th>Economic potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>Shared solar collectors per city</td>
<td>Eindhoven</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>-2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Bio</td>
<td>Biogas</td>
<td>Eindhoven</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Geothermal energy</td>
<td>Eindhoven</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Combined heat &amp; power (CHP)</td>
<td>Thermal energy storage - local opportunities for CHP</td>
<td>Eindhoven</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Heating grid</td>
<td>Eindhoven</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Energy storage</td>
<td>Hydrides</td>
<td>Eindhoven</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Power to gas</td>
<td>Eindhoven</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Distributed thermal energy storage (e.g. Ecowatt)</td>
<td>Eindhoven</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Technology solutions with low exergetic value

The table on page 74 shows the different technologies with a low exergetic value.

Outside Eindhoven

We start with sustainable solutions located outside Eindhoven offering usable thermal energy. These can be covered quickly: no suitable technologies are available, because it is not possible to transport energy over a distance. This also shows that when the gas runs out, the solution will currently have to be found locally, in Eindhoven.

Inside Eindhoven

As already indicated, most solutions for thermal energy need to be found locally in Eindhoven, except for the two ‘high exergy’ solutions using biogas or bioliquid.

Score on value drivers

We will review the list of technology options for each of the value drivers.

Efficiency in the reduction of fossil energy and contribution to sustainability

Most solutions score good or very good. Biofermentation scores lower because this technology still has to compete with food supplies. Geothermal energy scores low because in Eindhoven, in particular, the heat containing layer in the ground is very deep. It cannot be assumed that this will become attractive at some time in the future as a result of developments in technology. This remains an option with positive potential.

Residual energy from power stations and industry scores slightly lower, because of its relatively low presence in Eindhoven. There is little industry with a high energetic value. That does not mean it cannot be used locally, but it will not be able to offer a total solution for Eindhoven as a whole.

Robustness

If we assume that we have good storage solutions for thermal energy, the robustness should not be such a big problem. Even though all kinds of incidents have been reported with Thermal Energy Storage, it should be possible to deal with the problems to a reasonable level with a good design.

In addition the grey energy infrastructure will remain in place in the coming years, and this will be able to absorb any shortfall. In terms of robustness of the availability of TES technology, the problems are less great than with electricity.

Economic value

It is very difficult to give a clear answer on the economic value. This depends on many local factors. In addition, the upscaling of thermal energy systems to 1200 connected homes and buildings (or for some technology solutions to even larger numbers) further increases their economic attractiveness.

In general there are a number of scenarios:

• There is relatively little industry with a high energetic value or power stations that could provide heating or cooling for large numbers of homes and buildings using residual heat, and where the buildings are also located close together. In this case a heating grid is an attractive option. But today’s industry no longer has an unlimited lifetime, so a costly heating grid to distribute heat from a very limited number of industries is a significant risk. As well as that, Eindhoven as a ‘park city’ has a relatively low population density, which means the heating network is likely to have a low density of consumers and as a result an unfavourable payback time.

• A distributed local Thermal Energy Storage system is chosen. Because the systems are highly localised, the distribution network can have a lower transport capacity and short transport times.

• Finally, there may also be building-related solutions which are connected to individual homes but have to rely on bioliquid, gas or similar systems when their limited thermal energy storage capacity is exhausted.

Social value

Most thermal energy technologies are neighbour- hood systems, which means they have little social added value. Real social value is only created, leading to a somewhat higher score, when energy is recovered through behaviour, or by means of solar collectors on the home or using residual heat (from showers, tumble dryers etc.).

Health & Comfort

We assume that together with the improvement of insulation, attention is also given to measures that maintain the quality of the indoor climate (e.g. ventilation etc.). Insulation usually means conditions inside the home are less affected by the outdoor climate, which is certainly positive in areas with a lot of traffic.
High exergetic sustainable energy solutions

Efficiency in the reduction of fossil energy and contribution to sustainability

Cluster | Technology | Applicable type of energy | Suitable location | Efficiency in the reduction of fossil energy | Contribution to sustainability | Robustness | Economic value | Social value | Health & comfort | Architectural value | Autonomy | Economic potential
---|---|---|---|---|---|---|---|---|---|---|---|---|---
Wind | At sea | Electricity | Exclusive Eindhoven | 5 | 6 | 1 | 5 | 4 | 5 | 7 | 6 | 4 | 1 | 1
Solar | Building related | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Solar | Solar collectors | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Bio | Biomass | Biofermentation | None | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Hydro | Hydro-electric power station | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Tidal power station | Tidal movement | Electrical energy | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Nuclear energy | Nuclear fusion | Nuclear fusion | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Algae | Photo bio reactor | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Energy storage | Reversible hydro-electric power stations | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Water storage reservoirs | Compressed air power stations | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Batteries | Hydro | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Power to gas | Power to gas | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Super-capacitors | Thermal storage at high temperatures (in combination with CHP) | Electricity | Exclusive Eindhoven | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1
Smart grid | Central management of supply and demand | Electricity | None | 6 | 7 | 6 | 6 | 6 | 5 | 7 | 6 | 4 | 1 | 1

The table on page 37 shows the different technologies with a high exergetic value.

In the high-exergy cluster, energy is relatively quick and easy to transport over distances, and even over time. Biogas and biofuels have this quality. Electricity has this quality in relation to transport over distance but, as indicated in “trends, opportunities and challenges”, bridging time differences is still very costly because there are not yet any low-cost means of storage.

Energy storage

In terms of energy generation, the efficiency is reasonable, with peaks for wind followed by PV and biomass (the scalability is limited through the lack of a primary fuel). Then there is the great unknown, nuclear fission. The possibility cannot be ruled out that within 20 years nuclear fusion – which overcomes the problems of today’s nuclear fission – will solve all our energy problems for good. The construction of the first nuclear fusion power station led by a consortium of countries will be started in the near future.

As already indicated, the storage of electricity is not yet highly scalable, which explains its low scores on all counts. This starts to be a problem as soon as more than 20-25% of energy is generated by sustainable energy sources like solar and wind power which are hard to plan. These already account for 25% of the power generated in Germany, which regu...
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lady dumps its surplus green energy to other countries. Without good and efficient storage of electrical energy or sustainable fuels that can be converted into electricity, we will continue to be dependent to a large extent on electricity generated from grey energy sources.

Finally the buzzwords ‘Smart Grid’, which mean different things to different people. In general, there are two variants: a large, centralised controlled system – the dream of many software and service companies – and a distributed control system that brings together supply and demand using smart market mechanisms. The interview with Alliander [Agterberg, 2013] showed the latter to be more effective at present than the variant with a large control system.

Robustness

At present there is nothing in the danger zone. But all systems that make it difficult to control the supply of energy on the basis of demand will continue to need grey electricity as well. So they may be able to supply electricity, but not always at the times when we need it. Exceptions are biomass, biofermentation and nuclear fission. As far as energy storage technology is concerned, only reversible hydroelectric power and pumped water storage have enough installed capacity to make a small contribution to robustness. The rest is at present still insignificant in terms of capacity.

Economic value

In terms of payback time, wind and solar power are reasonable options. Water-based generation requires large initial investments, in some cases so high that potentially interested parties are not even prepared to carry out a pilot. Enough has already been said about energy storage: it is absolutely too expensive. Smart grid, as long as it is not top-down and municipality-specific, can be affordable – provided that the ‘smart’ can be managed, and at present this is hardly the case. Which is why this term is used to refer to all kinds of things that it does not really cover.

Social value

Robustness

Health & Comfort

Here too the difference is mainly in the changes that need to be made in homes and buildings, in particular. All non-local electricity generation requires little if any changes to homes, which means they score highly. All building-related technologies have a moderate score. Nuclear fusion, hydrogen and high-temperature thermal energy storage (700°C) are technologies that can cause serious consequences if anything goes wrong. Despite all the statistics, disasters such as Chernobyl and Fukushima have given nuclear fission a dangerous and unhealthy image. And the storage of radioactive materials completes that negative picture. Which leads to a poor score on these criteria.

Economic potential

All the technologies that generate electricity and store it outside Eindhoven get very poor scores. Exceptions are PV panels, building-related wind systems and smart grid technology. These may see the development of business from the present local knowledge economy.
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About LightHouse & the TU/e Intelligent Lighting Institute

The TU/e Intelligent Lighting Institute (ILI) was established in 2010 to investigate novel intelligent lighting solutions that will become within our reach by the large-scale introduction of LED technology, with a special emphasis on how these new solutions might affect people. We do this in collaboration with departments of the TU/e and partners in the public and private sectors. The lighting research performed at ILI is producing unique know-how and a technological head start for the participating parties, the Brainport Region, and as part of Europe.

Research

ILI’s mission is to search for revolutionary lighting solutions. It does this using an interdisciplinary approach that takes society as its laboratory. Well-being and sustainability are given top priority in all facets of its research and resonate throughout all of the strategic programs.

Five lines of research

The lines of lighting research at ILI have been created to address concrete issues faced by society. This approach is also known as ‘design for need’. The research programs take a holistic approach that takes society as its laboratory. Well-being and sustainability are given top priority in all facets of its research and resonate throughout all of the strategic programs.

- The Brilliant Streets research program aims at future outdoor lighting systems. Outdoor lighting is there to enhance traffic safety and to increase feelings of comfort and safety for people on the street. This goal remains, but opportunities for advanced applications are aplenty because of technological advances: new lighting technology (LED), advanced sensing, wireless communication and embedded processing.
- The Open Light program explores all of the possibilities of a particular technology, without any preconceived application ideas.
- Computational methods for illumination optics and rendering of light patterns
- If researchers in the No Switches Allowed program get their way, radical change is on the way: lighting will become interactive, new lighting technology (LED) and other innovations will become possible, and allow for precise control of lighting. It is, however, not known how people experience adaptive lighting and what this brings about emotionally. The challenge is to use technological advances to improve user experience while minimizing energy use. Brilliant Streets regards outdoor lighting systems and one of the subsystems of a Smart City. Sensing and communication capabilities will be used in the future to enhance city services.
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Brilliant Streets

The Brilliant Streets research program aims at future outdoor lighting systems. Outdoor lighting is there to enhance traffic safety and to increase feelings of comfort and safety for people on the street. This goal remains, but opportunities for advanced applications are aplenty because of technological advances: new lighting technology (LED), advanced sensing, wireless communication and embedded processing.

These new technologies make interactive systems possible, and allow for precise control of lighting. It is, however, not known how people experience adaptive lighting and what this brings about emotionally. The challenge is to use technological advances to improve user experience while minimizing energy use. Brilliant Streets regards outdoor lighting systems and one of the subsystems of a Smart City. Sensing and communication capabilities will be used in the future to enhance city services.

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This research report is a deliverable of the project Vision and Roadmap Eindhoven Energy-Neutral in the Built Environment 2045. In this co-creation project with various stakeholders from government, industry and research institutes a desired future scenario has been developed for Eindhoven, with a focus on energy in the built environment. With this desired scenario an investigation has been carried out into what is needed and possible in the shorter and longer term to realise the defined ambitions. The research covered sustainable behaviour, sustainable technologies and sustainable organisation. With the resulting roadmap a number of short-term goals have been defined that build on running activities and take concrete steps to move into the desired direction. The project to create a vision and roadmap for energy in the built environment has been completed. Further steps will be made in the working groups that will be made.

For more information: www.ili-lighthouse.nl/EhvEnergyneutral2045.html

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