

## 3.2. Participative innovation in smart urban lighting

### Introduction

The world is rapidly transforming [1]. Economic, ecological and technological developments transcend existing boundaries and challenge the way we innovate [2]. The challenge we face is to reinvent innovation as well, changing the way organisations and industries innovate and cooperate. Only with a new approach we can design a better future: an approach where stakeholders from government, organisations, companies and users participate in new ways of collaboration [3]; an approach where solutions are realised that makes our society future-proof. Participatory innovation means that the innovation team changes: expanding beyond the boundaries of the own organisation. For organisations and companies, this is a huge step. Every partner must be willing to think and act beyond their own borders and participate in a joint effort. Participative innovation is a new way of working, where new challenges are encountered. In the field of urban lighting, this transformation is strongly felt. This paper will further explore the challenge and describe a rich case study where participative innovation is used to rethink, redesign and realise the solutions to transform urban lighting from functional lighting to improving social quality.

New lighting technologies are creating a revolution in the lighting industry. The lighting industry will go through an evolution similar to the development in computing since the invention of the first transistor. In the next 12 years, 80 billion light bulbs will be replaced by LEDs. LED technology offers many advantages, such as chromaticity control, better light quality, and higher efficiency [4].

One of the application areas for new lighting solutions is urban lighting. Cities see great opportunities in the newest lighting technologies and want to embark on the transition towards energy savings and cost reduction and, at the same time, contribute to other values such as city marketing or economic development by enabling the 24/7 economy. Visionary cities also see opportunities to become a creative hotspot where societal challenges drive new lighting innovations.

However, making the right decision is not an easy task keeping in mind costs, sustainability and societal impact in the short and longer term. With the extended possibilities that LEDs offer and integration in smart sensor networks, new opportunities arise to further reduce energy use and light pollution, and increase people's sense of perceived personal safety and comfort at the same time.

However, there is still a lack of experience and knowledge on the impact of smart urban lighting solutions [5]. Companies are not able to test these solutions in the field without collaboration with municipalities and, on the other hand, municipalities hesitate to invest in solutions that are 'not ready'.

The challenge is to formulate a vision that extends beyond the economic value of urban lighting alone, and to create a roadmap to support short-term investment decisions that will enable further developments in the future. This requires a participative approach in which businesses, governmental organisations and knowledge institutes collaborate to achieve a high quality of life with smart urban lighting. The participative approach takes place on two levels:

- the creation of a vision and roadmap for a liveable city to identify the underlying principles for a municipality to guide further innovation towards improving the quality of life in the city;
- experimenting with intelligent lighting solutions in real-life settings to explore and learn how smart lighting solutions can contribute to the well-being of the citizens in the city.

The city of Eindhoven aspires to be a front runner in innovative, intelligent lighting solutions that contribute to a high quality of life in the city. The city already has a long-standing tradition of working in a triple helix structure in the Brainport Region. Building on this tradition, LightHouse, the solution partner of the Intelligent Lighting Institute (ILI) at the Eindhoven University of Technology, developed a participative approach to create a vision and roadmap. The approach will be described here using the case of urban lighting for the city of Eindhoven.

### Approach

The City of Eindhoven is currently faced simultaneously with a number of interrelated issues about public lighting, which can be formulated as follows.

- Firstly, there is a concrete question about the replacement of 21 000 street lights in the city: is it best to replace these all at once with LED lamps? If this investment were to be made now, the replacement budget would no longer be sufficient for further renewals.
- The City of Eindhoven is working together with 10 other European cities in a European INTERREG IVC PLUS project to define public lighting strategies for sustainable cities. The city needs to put forward a strategy and action plan as

part of this project, and wants to submit a well-founded strategy with a scope that extends further than simply short-term energy savings.

- Projects are also currently running in other public domains as well as public lighting, for example e-care, e-learning and e-traffic. These are investigating whether a city-wide infrastructure is necessary, and what would then be viable business models to recover the associated investment. Up to now, no simple and convincing financial answer has been found within the sphere of the current operations.
- The city aims to take the role of 'lead user', through which the city is made available for innovations developed by others (such as commercial parties or creative businesses). And, there is a wish to engage with citizens in different ways, surpassing the standard idea of 'citizen involvement'.

The conclusion that the city draws from the developments outlined above is that more detailed consideration is needed on the question of LED lighting than has been the case up to now. Broad acceptance — also among the citizens of Eindhoven — demands a clear proposition on the basis of which well-founded decisions can be taken.

The request from the City of Eindhoven's public lighting department to LightHouse was to formulate a vision extending beyond public lighting alone, together with a roadmap to allow decisions to be taken for short-term measures that will not prove to be barriers to longer-term developments. In the project, a participative innovation approach was applied involving the triple helix in every step.

To formulate a vision and roadmap for urban lighting in Eindhoven, extending to 2030, the project was divided into a number of phases. First of all, the current situation and ambition level of the municipality were analysed. Then, with the help of the future telling research method, the most important drivers for change for a future city with a high quality of life were identified and used to create a desired scenario for Eindhoven in 2030. To realise this scenario, a roadmap was made plotting the possible technological developments and required organisational changes together with the corresponding timeline. The insights gained into developments in societal, technological and organisational aspects have led to an innovation plan describing the concrete steps that can be taken in public-private collaboration to achieve the desired future of Eindhoven in 2030 (Figure 1).

Figure 1: The approach to a vision and roadmap for the City of Eindhoven in 2030

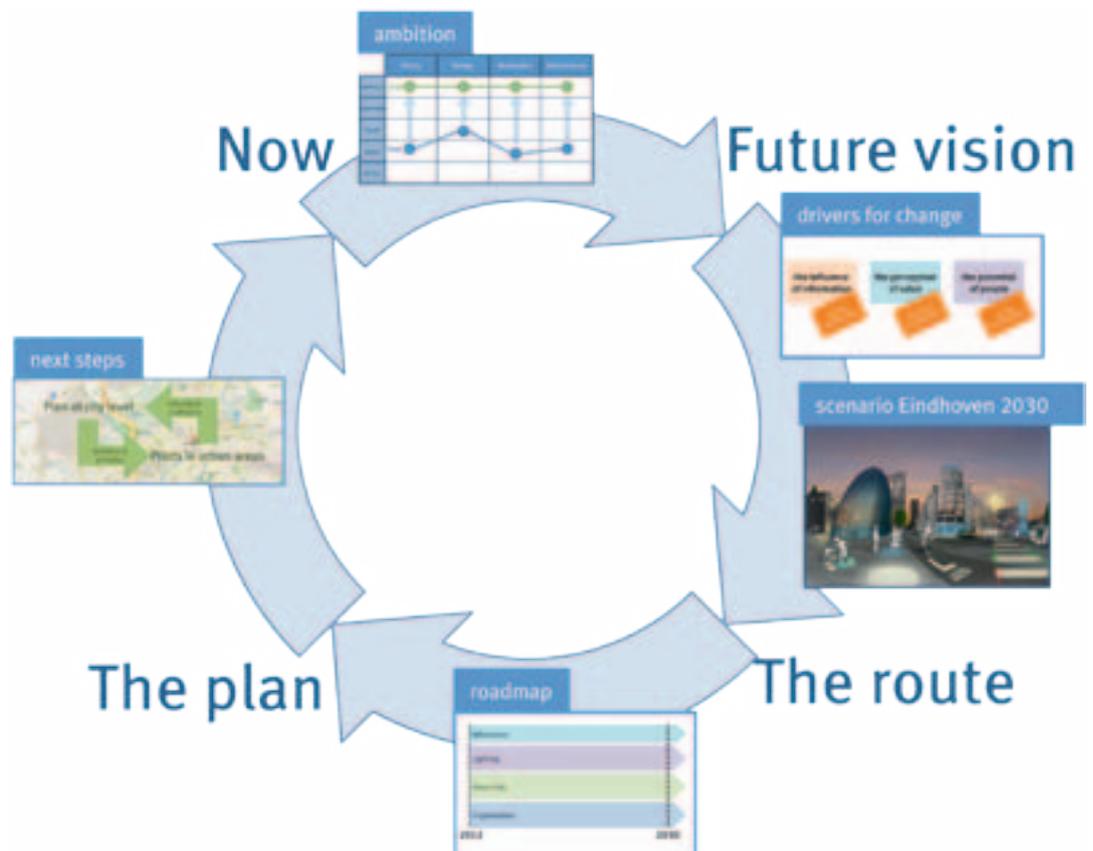


Figure 2: The reference model for sustainable urban lighting

● Selfassessment 2012

● Ambitie 2015

● Ambitie 2030

Level	Policy development					Design process					Realization process					Maintenance process							
	Defining ambition	Sustainability scope	Lighting innovation	Decision process	Design aspects	Stakeholder involvement	Contract management	Project management	Stakeholder management	Configuration management	Quality management	Progress monitoring	Defining ambition	Sustainability scope	Lighting innovation	Decision process	Design aspects	Stakeholder involvement	Contract management	Project management	Stakeholder management	Configuration management	Quality management
5 <b>Visionary</b>	<ul style="list-style-type: none"> <li>- Driving policy development through thought leadership</li> <li>- Yearly vision and roadmap</li> <li>- Involvement of quadruple helix in the creation of a shared vision</li> <li>- Thought leader</li> </ul>	<ul style="list-style-type: none"> <li>- Quality of life in public space as a whole</li> <li>- Improving quality of life of citizens</li> <li>- Public space as a whole (incl. lighting)</li> <li>- Objective reviews show 'best in class'</li> </ul>	<ul style="list-style-type: none"> <li>- Exploring new opportunities through experimental projects (innovation)</li> <li>- Publication and presentation of results to others (sharing)</li> </ul>	<ul style="list-style-type: none"> <li>- Policy and roadmap drives decisions</li> <li>- Autonomous, knowledgeable and experienced teams across quadruple helix</li> <li>- Specific validation of new solutions</li> </ul>	<ul style="list-style-type: none"> <li>- Exploration and integrated decision making</li> <li>- Integrated decision making</li> <li>- Reflection from multiple views</li> <li>- Iterative approaches of experimenting and testing of new opportunities</li> <li>- Setting new norms</li> </ul>	<ul style="list-style-type: none"> <li>- Learning process across organisations in the quadruple helix</li> <li>- Respecting each other's contribution as thought leaders</li> </ul>	<ul style="list-style-type: none"> <li>- Joint roadmaps in a stakeholder network</li> <li>- Roadmaps involving quadruple helix, stakeholders see as partners</li> <li>- Distinguishing between repetitive and innovative projects</li> <li>- Risks identification from full quadruple helix</li> </ul>	<ul style="list-style-type: none"> <li>- Quadruple based management of targets and risks</li> <li>- Project management on targets</li> <li>- Targets monitored and adjusted by several stakeholders</li> <li>- Dynamic assessment of changes</li> </ul>	<ul style="list-style-type: none"> <li>- Involvement</li> <li>- Involvement of stakeholders in planning of realisation project</li> <li>- Best timing for the project based on minimising burden</li> </ul>	<ul style="list-style-type: none"> <li>- Quadruple level integrated configuration management</li> <li>- Integrated configuration management system maintained by several stakeholders</li> <li>- Dynamic assessment of changes</li> </ul>	<ul style="list-style-type: none"> <li>- Continuous improvement based on emerging pattern recognition</li> <li>- The installed base is part of an on-going innovation process</li> <li>- Emerging pattern recognition</li> <li>- Integrated maintenance management through intelligent systems</li> </ul>	<ul style="list-style-type: none"> <li>- Continuous improvement in quadruple helix</li> <li>- Continuous collection of feedback from the quadruple helix</li> <li>- Pro-active attitude of quadruple helix towards the shared vision</li> <li>- Joint improvement plans involving the quadruple helix</li> </ul>											
4 <b>Embedded</b>	<ul style="list-style-type: none"> <li>- Program management to meet future needs of end-users</li> <li>- Master plan with ambition</li> <li>- In part of total chain on future needs</li> <li>- Program management</li> </ul>	<ul style="list-style-type: none"> <li>- Social &amp; ecological sustainability of light in public spaces</li> <li>- Sustainability incl. social factors</li> <li>- Urban lighting as a whole</li> </ul>	<ul style="list-style-type: none"> <li>- Fast adoption of new functionalities</li> <li>- Fast capitalization of new functions</li> <li>- Keeping track of new developments</li> </ul>	<ul style="list-style-type: none"> <li>- Master plan drives decisions</li> <li>- Incorporating new insights or solutions in the design</li> <li>- Involvement of end-users and relevant stakeholders in decisions</li> </ul>	<ul style="list-style-type: none"> <li>- Applying proven insights</li> <li>- New and proven insights are integrated into design decisions of the projects</li> <li>- Applying new solutions in specific projects</li> </ul>	<ul style="list-style-type: none"> <li>- Monitoring effectiveness</li> <li>- Monitoring effectiveness of participation of various stakeholders</li> <li>- Stakeholders suggest involvement</li> </ul>	<ul style="list-style-type: none"> <li>- Specifying opportunities for suppliers</li> <li>- Suppliers involved in co-development</li> <li>- Supplier performance evaluation on goals in the total chain</li> </ul>	<ul style="list-style-type: none"> <li>- Qualitative management of targets and risks on network level across the total chain</li> <li>- Risk identification in separate organisations and impact on total chain</li> </ul>	<ul style="list-style-type: none"> <li>- Time(s) &amp; relevant information</li> <li>- Planning to minimise disturbances for stakeholders</li> <li>- Prior notice to stakeholders</li> </ul>	<ul style="list-style-type: none"> <li>- Chain level integrated configuration management</li> <li>- Configuration management system for design changes</li> <li>- Impact assessment of design changes</li> </ul>	<ul style="list-style-type: none"> <li>- Improvement based on monitoring installations</li> <li>- Continuous monitoring of individual installations</li> <li>- Improvement based on insights from data</li> <li>- Proactive and reactive maintenance based on real time information from the system</li> </ul>	<ul style="list-style-type: none"> <li>- Structural improvement in the total chain</li> <li>- Structural process in place to monitor if targets of the master plan are met</li> <li>- Monitoring if adaptation of plans or actions is needed to achieve the targets</li> </ul>											
3 <b>Depth</b>	<ul style="list-style-type: none"> <li>- Program of coherent projects to meet organisational ambitions</li> <li>- Ambition defined on organisational level</li> <li>- Coherent program of projects</li> <li>- Support from all relevant departments</li> </ul>	<ul style="list-style-type: none"> <li>- Ecological effectiveness of public and private lighting systems</li> <li>- Sustainability incl. ecological effectiveness</li> <li>- Relation between projects</li> <li>- Urban lighting incl. private systems</li> </ul>	<ul style="list-style-type: none"> <li>- Applying new lighting products for multifunctional purposes</li> <li>- Multifunctional lighting: safety, experience, navigation and traffic regulation</li> <li>- Applying newly available products in the program of projects (reactive follow)</li> </ul>	<ul style="list-style-type: none"> <li>- Program targets drive decisions</li> <li>- Avoiding sub optimisation</li> <li>- Issues resolved on program level</li> </ul>	<ul style="list-style-type: none"> <li>- Meeting integral and extended targets</li> <li>- Targets defined beyond common rules and regulations</li> <li>- Targets considered integrally</li> </ul>	<ul style="list-style-type: none"> <li>- Process management</li> <li>- Having specific stakeholders for specific decisions</li> <li>- Stakeholders are aware and prepared</li> </ul>	<ul style="list-style-type: none"> <li>- Specifying generic targets for suppliers</li> <li>- Tendering for proven concepts and technologies</li> <li>- Supplier performance evaluation on project targets</li> <li>- Supplier management process in place</li> </ul>	<ul style="list-style-type: none"> <li>- Qualitative management of targets and risks on organisation level</li> <li>- Project and program management on organisational targets</li> <li>- Quantitative targets on project level</li> <li>- Risks identification in separate projects and impact on program targets</li> </ul>	<ul style="list-style-type: none"> <li>- Relevant information</li> <li>- Planning based on important external factors</li> <li>- Relevant information to most important stakeholders get relevant information</li> <li>- Additional info through standard channels (e.g. website)</li> </ul>	<ul style="list-style-type: none"> <li>- Organizational level configuration management</li> <li>- Tracking and controlling of documentation on changes</li> <li>- Configuration baselines and configuration checks audits</li> </ul>	<ul style="list-style-type: none"> <li>- Preventive actions on organisational level</li> <li>- Complaint analysis and comparison across installations and projects in the city</li> <li>- Sharing solutions across projects and installations</li> <li>- Proactive and reactive maintenance based on plans</li> </ul>	<ul style="list-style-type: none"> <li>- Structural improvement on organisational level</li> <li>- Structural data collection on project performance and on organisational level</li> <li>- Monitoring if targets on organisational level are met</li> </ul>											
2 <b>Aware</b>	<ul style="list-style-type: none"> <li>- Project level targets and activities</li> <li>- Targets defined on project level</li> <li>- A commitment is responsible in a sense of past performance</li> <li>- Track record of successful projects</li> </ul>	<ul style="list-style-type: none"> <li>- Material use &amp; energy consumption in public lighting systems</li> <li>- Sustainability incl. 'zero emission' total product life cycle</li> <li>- Scarce resources and energy consumption</li> <li>- Lamps and luminaires managed by the municipality</li> </ul>	<ul style="list-style-type: none"> <li>- Applying standard products for functions and experience</li> <li>- Considering experience of citizens and visitors</li> <li>- Applying standard products from catalogues, incl. impact on experience</li> </ul>	<ul style="list-style-type: none"> <li>- Alignment with project targets</li> <li>- Project targets drive decisions</li> <li>- Issues resolved through escalation</li> </ul>	<ul style="list-style-type: none"> <li>- Meeting extended targets</li> <li>- Proactively following general rules and regulations and upcoming trends</li> <li>- Staying within budget targets</li> <li>- Applying new technologies to meet extended targets</li> <li>- Staying up to date with new rules and regulations</li> </ul>	<ul style="list-style-type: none"> <li>- Active involvement</li> <li>- Some important stakeholders are always involved in design projects</li> </ul>	<ul style="list-style-type: none"> <li>- Specifying standard products for systems for suppliers</li> <li>- Requirements specification for commercially available products</li> <li>- Supplier performance evaluation on project specification</li> <li>- Supplier agreements</li> </ul>	<ul style="list-style-type: none"> <li>- Qualitative management of targets and risks on project level</li> <li>- Project management on product targets</li> <li>- Reactive risk identification based on incidents/threats</li> </ul>	<ul style="list-style-type: none"> <li>- Minor information</li> <li>- Planning based on internal planning and capacity</li> <li>- Information through standard channels on the execution of the works - no detailed information available</li> </ul>	<ul style="list-style-type: none"> <li>- Project level configuration management</li> <li>- Documentation on project/installation level</li> </ul>	<ul style="list-style-type: none"> <li>- Reactive actions for structural improvement</li> <li>- Structural resolution of complaints within projects</li> <li>- Reactive maintenance with best response based on pareto analysis of failures &amp; stock of spare parts</li> <li>- Creative maintenance through periodic replacements of parts</li> </ul>	<ul style="list-style-type: none"> <li>- Structural data collection</li> <li>- Data on project performance in relation to the targets is collected</li> </ul>											
1 <b>Ad-hoc</b>	<ul style="list-style-type: none"> <li>- Ad-hoc and informal activities</li> <li>- Individual ambitions (on managerial or operational level)</li> <li>- Informal networks</li> <li>- No structured processes, and/or skill levels defined</li> <li>- No consequences when targets are not met</li> </ul>	<ul style="list-style-type: none"> <li>- Regulation driven</li> <li>- Adherence to regulations and rules</li> <li>- Scope is dependent on individual view</li> <li>- Under-influence of elections and governmental terms</li> </ul>	<ul style="list-style-type: none"> <li>- Applying standard products for functional lighting</li> <li>- Functional focus on safety in the city</li> <li>- Products are purchased from catalogues, with focus on function &amp; costs</li> </ul>	<ul style="list-style-type: none"> <li>- Ad-hoc decisions by people involved</li> <li>- Issues may lead to not meeting ambitions</li> </ul>	<ul style="list-style-type: none"> <li>- Solving issues</li> <li>- Complaints of citizens</li> <li>- Reactive approach to new rules and regulations</li> </ul>	<ul style="list-style-type: none"> <li>- None</li> <li>- Ad-hoc stakeholder involvement</li> </ul>	<ul style="list-style-type: none"> <li>- Purchasing standard products</li> <li>- Standard products for standard applications</li> <li>- Supplier performance evaluation on individual deliveries</li> <li>- Ad-hoc selection of suppliers</li> </ul>	<ul style="list-style-type: none"> <li>- No structured project and risk management</li> <li>- No performance indicators are defined by the realization project</li> <li>- No risk management procedure in place</li> </ul>	<ul style="list-style-type: none"> <li>- No stakeholder management</li> <li>- Execution based on internal planning and capacity</li> <li>- No information provision</li> </ul>	<ul style="list-style-type: none"> <li>- No configuration management procedure in place</li> </ul>	<ul style="list-style-type: none"> <li>- Handling of individual complaints</li> <li>- Individual complaints are analysed and resolved</li> <li>- Reactive maintenance based on incidents</li> <li>- No stock of parts</li> </ul>	<ul style="list-style-type: none"> <li>- None</li> <li>- No structural collection of feedback on projects</li> <li>- No structural monitoring of progress to meet targets</li> </ul>											

### Now: defining the ambition

Using the ILI Reference Model for Sustainable Urban Lighting [6], a self-assessment was performed to find out where Eindhoven stands in terms of the processes relating to policy development, the design and realisation of lighting projects in the city, and the maintenance and monitoring of whether the ambitions expressed in the policy are achieved. Based on a process of self-reflection with municipal staff members, the city's present position on the reference model was identified: the blue scores in Figure 2. The self-assessment revealed that the city has most of its processes well organised. Eindhoven is leading in stakeholder involvement but the municipal staff members are not making their views felt to a sufficient extent in the discussions. That means the city runs the risk that the interests of citizens do not carry sufficient weight in innovative projects. To reach a higher score, the city needs to profile itself not as a 'lead user' but as a fully involved partner in the triple helix.

The results of the self-assessment were discussed in a workshop where the ambition level was also defined. This revealed that the ambition of the city is at visionary level: see the green scores in Figure 2. Eindhoven wants to apply innovative technologies to address socially relevant issues in partnership with the triple helix and with clear citizen involvement (quadruple helix). The city recognises the importance of innovation for the economic development of the region, is prepared to accept risks that are inherent in innovation, and regards its own primary task as safeguarding its citizens' interests.

This ambition requires collaboration in a quadruple helix structure (with the municipality, business parties, research institutes and citizens as equal partners). The city council has to develop from being a lead user, putting the city forward as a test bed for suppliers, towards a full partner, safeguarding public interests through collaboration in the quadruple helix structure.

### Future vision: Scenario Eindhoven 2030

With the help of the future telling Research method, a vision was created [7]. The method uses a set of cards with 64 future trends (Figure 3). Relevant trends with a high impact on a liveable city in 2030 are identified in interviews with thought leaders from industry, knowledge institutes and governments. These trends are then further illustrated with rich stories about possible futures, supported by examples.

An analysis of these rich stories reveals three drives for change.

The first driver is the growing influence of information (left column in Figure 4). Our behaviour will be driven by ubiquitous information (automatically gathered by sensors or added by users through social media). This will allow systems to take over complex tasks, especially when biological and sociological factors are included in the process of digitisation. This will further empower people through good technology applications. This driver triggers a number of questions: is it enough, and is it fair, for the city just to retain the task of social safety, when efforts are being made all around us to create an open grid? Who will decide

Figure 3: The future telling card set



who's allowed to do what? Who is the owner of a network and information (and are they trustworthy)? Technology becomes a social design process; this is an ethical design issue, in which a code of conduct also needs to be designed by involving all stakeholders. To allow this driver to develop in the direction of a positive society, an ethical recalibration is a prerequisite.

The second driver is the perception of value (middle column in Figure 4). The Netherlands has an excellent 'liveable environment', we have nothing to complain about, but the awareness of scarcity is beginning to take hold. There needs to be some kind of stimulus to make alternatives more attractive. People will start to use information to deliver on their individual needs and use self-management and take responsibility for their own situation in all kinds of areas: care, social safety, energy. There will be an increasing awareness that we all have duties and responsibilities, and innovation will increasingly start from a social perspective. The awareness will grow that scarcity isn't just a question of money (it also means attention, love). In this context, is it enough for the city to just put itself forward as a Living Lab, without having its own point of view about how to deal with innovation and change? Who is in control? Which prerequisites will have to be facilitated? What is the new economic system? There will be a revaluation of value: new value models (not just business expressed in euros) that strive for reciprocity, for forms of value beyond money. This second driver, the perception of value,

requires an economic recalibration, in which new forms of value beyond money are included.

The third driver is the potential of people (right column in Figure 4). There is increasing independence: in work (partly as the result of circumstances, partly through choice) and in education (where financing of talents is expected to take place, instead of institutions). New networks are being formed based on individuals' own, deliberate choices, where people decide for themselves with whom they want to do things. New (ad hoc) networks arise across boundaries. Cities (regions) have an important role in bringing creative and ambitious people together, working on development, based on a vision, towards a higher goal. New developments and innovations start in attractive cities. Is it then enough, and is it fair, to use a smart grid to provide openness but without defining the framework? What role does the city take in relation to creating a framework, legislation, opportunities, and in developing a vision and making choices? Bringing parties together works for people who can express themselves, but how can you safeguard the interests of the weaker members of society in the quadruple helix? This driver, the potential of people, asks for a social recalibration.

With the drivers for change, a discussion was started on their impact on Eindhoven in 2030. This resulted in a scenario for the future vision for Eindhoven specifically. A multipurpose, smart lighting grid will

Figure 4: Three drivers for change

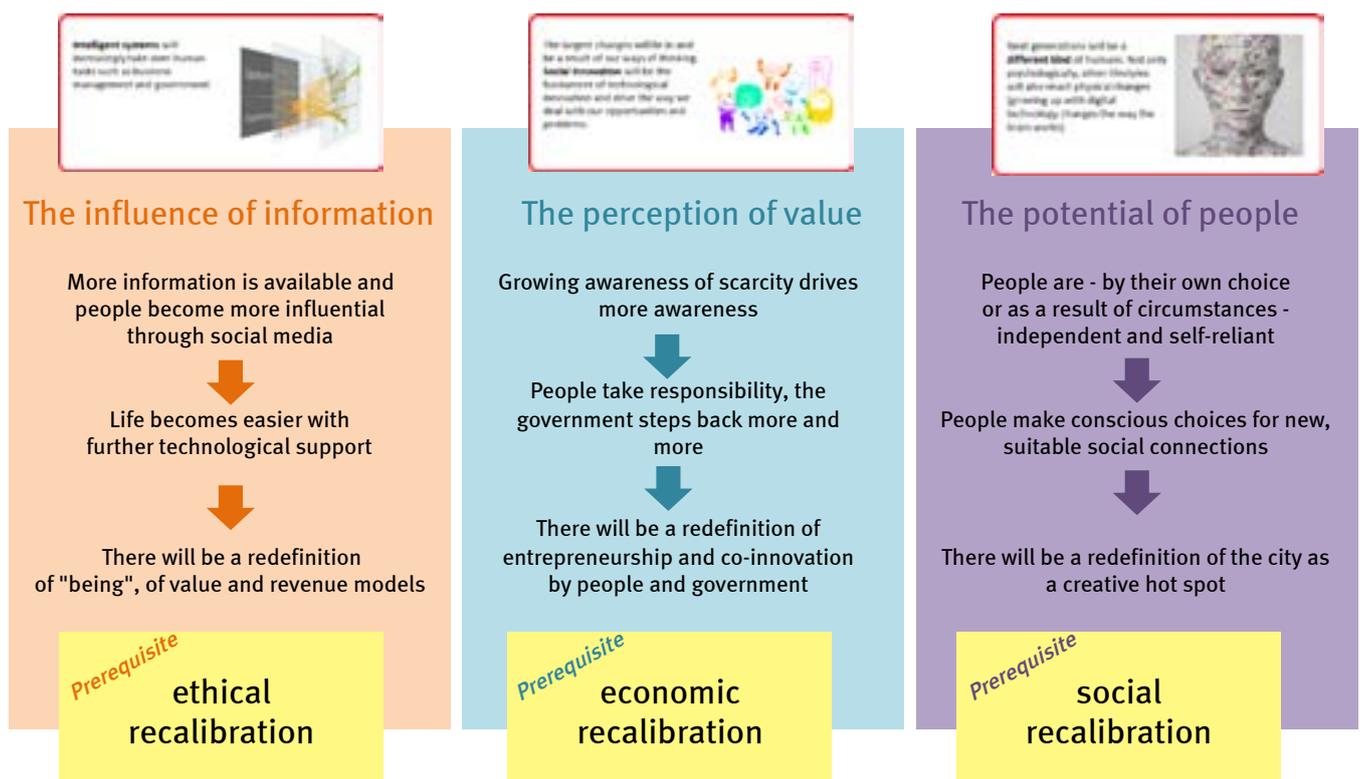


Figure 5: Eindhoven in 2030



be introduced, combining ICT (IP), energy and lighting functions. This will create new possibilities (and with them new design opportunities) in the ways the social and urban space can be used. The municipality will have an important role in providing the smart lighting grid as a public utility, including lighting in its broadest sense (from functional lighting to multimedia art projections), and safety in its broadest sense, including social safety, traffic systems and air quality. In 2030, the public space will no longer be just a 'transit' space, but an extension of living space. The municipality will be responsible as the provider and will ensure the smart lighting grid serves society's needs. Processes will have to be set up to safeguard the public interest and to make the grid accessible for all kinds of initiatives (citizens, commercial) to ensure continuous development in and through the quadruple helix. This also means creating space for experiments by providing (temporary) Living Labs to co-create and test together with partners.

Figure 5 shows a visualisation of the scenario with a number of examples to provide inspiration for the roadmap sessions reviewing the technological opportunities to realise the scenario 2030.

#### *The route: Roadmap Eindhoven 2030*

The Eindhoven 2030 scenario served as an inspiration to explore the technological opportunities and to actually put them into practice. The roadmap methodology [8] was used in workshops with representatives of the triple helix. Experts from industry

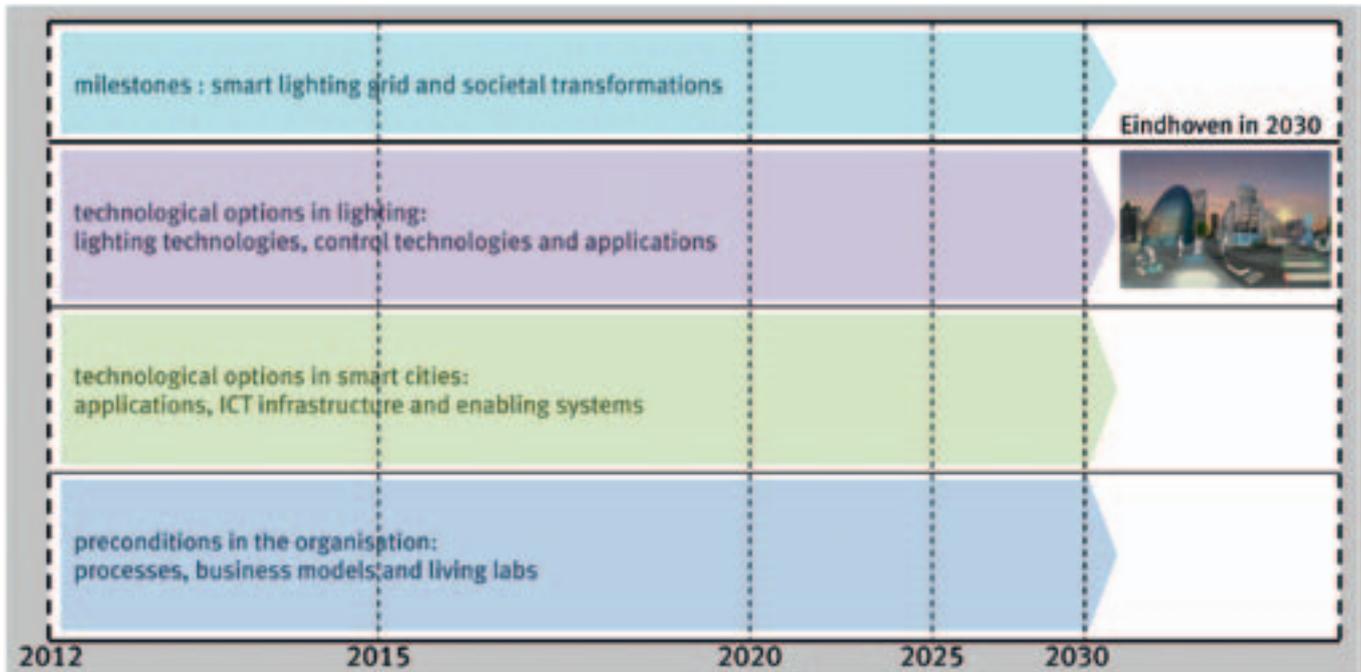
including Philips, Schreder, Cisco and Cofely and knowledge institutes including TNO and TU/e have indicated the possibilities they see in the areas of lighting and smart technology and placed them on a timeline. They have also highlighted the pre-conditions for the organisation. This topic was also discussed in a session with personnel from the municipality.

Figure 6 shows the elements of the roadmap. The raw data from the roadmap workshops have been clustered on a number of important elements placed on a timeline. This provides insight in the steps for the development of a smart lighting grid.

Lighting technologies will first be improved on energy performance. In the near future, the focus will shift towards more dynamic and interactive systems that allow 'light-on-demand' in interactive lighting scenarios. Interaction with real-time information makes social systems possible that are more responsive to the needs of citizens. In the longer term, the lower energy requirements of the light sources and controls will make small, self-sufficient lighting systems achievable that disappear in the context of their environments. In 2030, the system will be invisibly integrated in the area and will interact through intuitive controls.

Developments in technologies for smart cities are currently focusing on realising a broadband infrastructure with many access points. In the near

Figure 6: Elements of the roadmap



future, the availability of open data from different sources will drive new systems development: firstly, as separate systems (e.g. traffic management, air quality systems, navigation systems, emergency systems) but later merging into a 'system of systems'. This will allow further optimisation of the use of energy across different services. Restrictions in energy consumption are expected to disappear in the longer term. This is, on the one hand, because systems are becoming increasingly efficient resulting in a decrease in consumption and, on the other hand, because of constant improvements in the generation of sustainable energy, which means more sustainable energy becomes available. By 2030, smart cities will be within reach through the integration of solutions for various urban services (energy, waste, mobility, care, lighting, etc.), communicating and coordinating their behaviour jointly.

The roadmap discussions also reveal required organisational changes. First of all, plans will need to be developed for the various areas in the city, with priority for socially important themes. Innovative tendering processes are needed that enable new business models in public-private partnerships. In fact, new ecosystems need to be created, in which innovation also plays a role in the longer term. In parallel, Living Labs will need to be set up to start co-creation in the quadruple helix on societal issues. A deeper understanding about the needs of the citizens will give rise to new products and services. The municipality will need to play an active role in defining new laws and regulations to

facilitate these innovations and also to ensure that the public interest is safeguarded.

Last but not least, the roadmap connects the technological options to the milestones in societal transformation to achieve the aspired vision. Firstly, a transition in the perception of people will take place as the awareness of scarcity drives better-considered choices. There is a shift to more social responsibility for themselves, others and the environment (not just 'me' but more 'we'). This results in a broader support for sustainability, with citizens who also expect the government to make better-considered, more responsible choices. Then, a transition in social connection takes place, where responsible people make good use of technology to create new and significant links with other people with comparable ambitions. If the government is withdrawing, self-management becomes increasingly important. The new social networks can also play a role in the Living Labs, with input on the desired activities, system behaviour and dynamic lighting scenarios. The next transition is in social innovation: enterprising people and cities will co-innovate on valuable solutions that contribute to higher ambitions. A smart city can only function if all parties in the quadruple helix act in a way that is carefully considered and contributes to a better quality of life in the city.

The complete roadmap is shown in Figure 7. A poster size version is available online (<http://www.ili-lighthouse.nl/DownloadroadmapEN.html>).



The roadmap shows that much is already possible in terms of technology. However, finding a payback model for the investment in public–private partnerships is much more of an issue. Different areas in the city demand different infrastructures and have different possibilities in terms of the payback model. Where, for example, the city centre requires high data rates to integrate video signals, lower data rates may be sufficient to control the lighting systems in some of the residential areas. It is also clear that some ‘customers’ for high bandwidth can be found in the city centre, thereby enabling other payback models. It, therefore, appears logical to differentiate the plans for the respective areas, while also taking into account the payback model and the stakeholder needs in each area.

The roadmap defines the societal drivers that determine the quality of life, but still little is known about the citizens’ perception of social cohesion or safety through new lighting solutions. With the roadmap, cities can take three concrete steps in the short term for specification and implementation.

To translate societal drivers into daily practice, citizens have to be involved and any consequences of lighting solutions on their perception have to be defined as leading questions for innovation. At the same time, short-term investment decisions should focus on flexible infrastructures that enable experimentation involving partners from the quadruple helix to find answers to these questions, starting participative innovation, exploring openness in the system architecture on all levels and creating viable business models. In this way, Living Labs are created; new products and solutions are co-designed and tested with the involvement of citizens. Thus, society learns and innovates together and becomes a creative hotspot where societal challenges drive new lighting innovations.

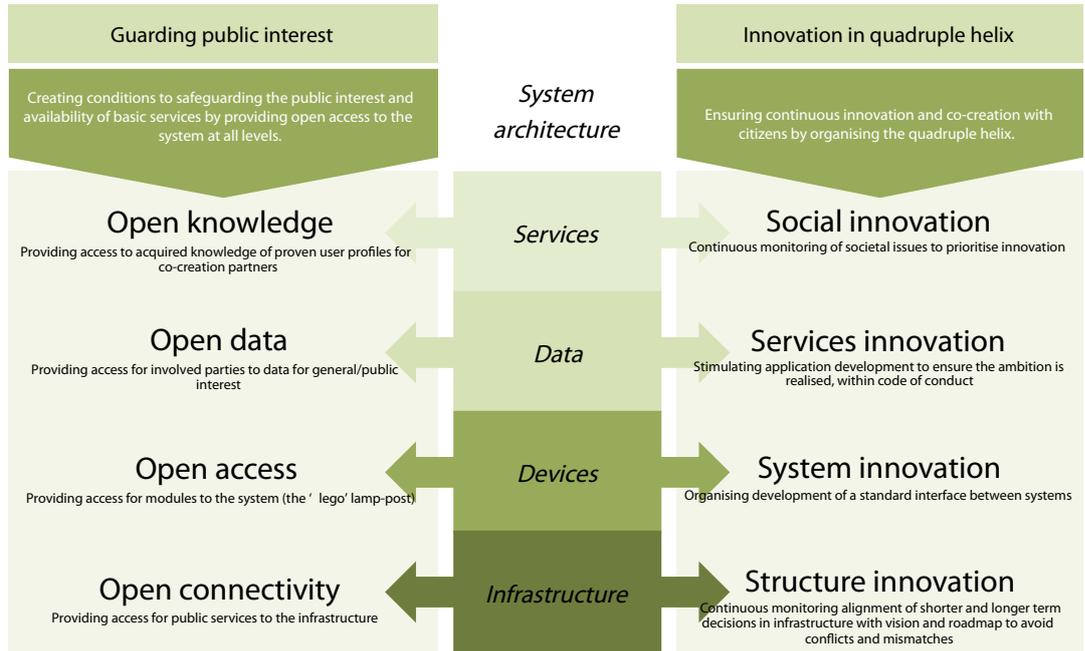
### *The plan: next steps*

Based on the vision and roadmap, future-proof follow-up steps can now be defined. Because the city’s ambition is to stay ahead in technology and innovation, it is important for the innovation process to be defined and anchored to allow continuous experimentation and development with new products and services. Although most parties (companies, knowledge institutes and the municipality itself) are aware that innovations relating to the smart lighting grid have to be handled in a different way to the standard tendering processes, it is not yet clear how the innovation process should actually be handled. Partnerships between public and private parties will change, and will focus mainly on knowledge integration to reach a total system concept and on generating new payback models. The municipality will have to safeguard public interests in these partnerships, which means it will have to take its full responsibility in the triple helix, while, at the same time, extending this into a quadruple helix by actively involving citizens.

To ensure innovation through the entire system, it is necessary to understand the system architecture. In Figure 8, four levels are distinguished in the architecture (centre column, from bottom to top): infrastructure, devices, data and services. Each of these levels is an enabler for the level above it, and innovation can take place at each level. To ensure innovation through the entire system, two aspects will need to be arranged:

- the openness of the system (left column in Figure 8): the municipality will have to ensure transparency at all levels of the system; for most commercial parties, this will conflict with their present business models, which, in many cases, are based on ownership of (parts of) the system;
- the organisation of innovation (right column): the municipality will have to take a controlling role in organising the partnerships in the quadruple helix.

Figure 8: Prerequisites for innovation



The municipality will have an important role to establish the preconditions for innovation. This includes the safeguarding of public interest and availability of the basic services by providing open access to the system at all levels: connectivity to the infrastructure for public services, access to the devices, access to data for public interest and access to acquired knowledge. It also includes ensuring continuous innovation and co-creation with citizens by organising the quadruple helix to innovate at all levels of the system: innovations in the infrastructure, innovations in the system of devices and developing a standard interface, innovation in services to drive development of new applications, and social innovation to prioritise societal challenges and issues that are deemed important by the citizens.

The concrete steps to be taken in the short term involve the creation of a plan at city level that

indicates ambitions and priorities. In parallel, pilots can be carried out in specific urban areas that provide a learning platform and scalability (Figure 9). There are big differences in the desired functionalities and dynamics: for example residential areas, shopping centres, industrial areas, ring roads, night-life areas or parks. In each area, experiments can be performed in a 'small' ecosystem to find viable payback models for the investment and new business models for new products and services. Participatory innovation can be anchored in the area by engaging the directly involved parties and citizens in the quadruple helix structure. The municipality can take the initiative in its role as a fully fledged partner. The small-scale pilots can be scaled-up once enough practical experience and confidence have been built through use.

Figure 9: Next steps



Concrete actions for the short term can be formulated as follows.

- Eindhoven as a Living Lab: setting up Living Labs and organising learning cycles, experimenting with innovative lighting solutions and learning to work in new collaboration structures; the quadruple helix.
- The municipality as an innovative organisation: anticipating the changing role of the municipality by setting up new processes by defining new roles and responsibilities to safeguard the public interests in innovation, from citizen involvement to co-innovation with citizens and organising the ethical debate.
- Towards Europe: the municipality can ensure continuous innovation by the way the project description is formulated, instead of simply specifying the delivery of a system or provision of a service. In case existing contracts and regulations cause limitations in the ability to do this, the municipality will have to take the lead in discussions with European authorities about necessary changes (e.g. in relation to the 'digital agenda') to enable innovative procurement and facilitating adaptations in standards and regulations for innovative lighting solutions.

In the coming years, innovation in public lighting systems will evolve from purchasing products and services developed by companies to participatory innovation in a quadruple helix structure. This also means that all partners will have to embrace mutual dependency in participative innovation and learning by doing.

### Conclusion

The challenge we faced was to formulate a vision that extends beyond the economic value of urban lighting alone, and to create a roadmap to support short-term investment decisions that will enable further developments in the future. We took a participative approach to innovation, in which businesses, governmental organisations and knowledge institutes were invited to collaborate to achieve a high quality of life with smart urban lighting.

In the creation of the future vision and technical roadmap for a liveable city, we invited many partners to think with us and share their ideas, experiences and visions. The result is not only an inspiring vision with a broad view, challenging the quality of life in cities in 2030. A collateral value is the adoption of the vision and roadmap by all participants: because they recognise their contribution to the story, they are willing to adopt the integrated story. The shared result is owned by all and this has an impact on the

acceptance of the roadmap in the municipality as well as in the cooperating parties and society.

However, a vision is one thing. The next step is implementation. The step towards implementation proves to be tough. Every partner must be willing to think and act beyond their own borders and direct short-term repayment. Every partner must be able to define their role in the innovation towards a better quality of life. This does not happen overnight, nor by itself. The challenge we face now also has to be shared by the participants, together with a willingness to adopt an experimental approach. This links closely to the transition our society is currently going through: with a growing influence of information and people, a changing perception of value and a social-driven approach.

This requires a new approach to innovation, where stakeholders from government, organisations, companies, and users participate in new ways of collaboration. An approach where solutions are realised that make our society future-proof; an approach where we participate in a redesign of the world while it keeps spinning.

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