Roadmapping for Sustainability; How to Navigate a Social, Political, and Many Systems-of-Systems Playing Field? A Local Initiative

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***Abstract*—The United Nations have defined 17 Sustainability Development Goals (SDGs). These goals cascade down to all governmental levels, such as EU, national, province, regional, and municipality. The realization of these goals requires developments in many systems, including non-technical systems (e.g. social, political, and ecological). One of the challenges is the complexity due to the large number of stakeholders (individuals, as well as many types of organizations) and the number of systems, all of them interacting and mutually dependent. A key function of SoS architecting is the creation and maintenance of the overview of the problem and solution space. SoS architects have many tools available to do this, such as conceptual modeling. In this paper, we will focus on Roadmapping as interaction tool between stakeholders. We are applying the tool at municipality level to study the tool's effectiveness.**

Keywords—Sustainability, Energy, transition, roadmap

I. Introduction

The 2018 IPCC report summary [1] clearly explains the urgency for sustainability measures. The focus of the report is the global warming, and the need to limit this warming to avoid huge global risks. Humanity knows about the severity of this problem for decades [2]. Rich describes in [2] how politicians in the period 1979-1989 nearly did the right thing. Unfortunately, one dominant politician followed his biased gutfeel and blocked humanity for decades [2].

A. The Global Sustainability Challenges

The United Nations have defined 17 Sustainability Development Goals (SDGs)[i], ranging from social and economic goals as No Poverty to ecologic and climate goals as Climate Action and Affordable and Clean Energy. These goals propagate to other governmental levels, such as EU[ii] and countries such as the Netherlands[iii]. These 17 goals are related; to achieve climate and ecologic goals, we need social and economic improvements globally.

B. Local Sustainability Challenges – a Case Study

Concerned citizens take action everywhere. In the Netherlands, we see a proliferation of local cooperatives working on renewable energy[iv]. These cooperatives take many forms. Some actively build PV-farms or wind turbines, while others focus on technical advice and education.

Three of the authors of this paper live in Best, a small town of 30 thousand inhabitants in the province Noord Brabant in the south of the Netherlands (see Fig. 1). Best has 12 thousand houses. The average income is 26k€/yr[v].

Fig. 1. Best in Noord Brabant in the south of the Netherlands.

This town has a cooperation named Best Duurzaam[vi], started in 2013, with 360 members in December 2018. The about 40 active volunteers of the cooperation have been quite productive; they have provided hundreds "sustainable living recommendations" and organized tens of educational meetings at schools and neighborhood centers.

The cooperation recently updated their strategy. As consequence, the cooperation decided to migrate to a project model with the goal of increasing effectiveness. This change triggered the idea of Roadmapping to provide a big picture as context for the projects.

The municipality has the formal responsibility for management of the town and most of its infrastructure. The management team of the municipality consists of a major and 4 aldermen, supported by about 240 employees working in 6 departments. Two aldermen cover together the sustainability aspects.

National legislation mandates that the municipality makes plans for sustainability. At the end of 2019, the municipality has to deliver a regional plan for energy and especially the heating of houses. This clearly shows that the municipality is one of the major stakeholders.

Preprint of https://doi.org/10.1109/SYSOSE.2019.8753844 IEEE SOSE 2019 in Anchorage, Alaska, USA ©2019 IEEE

There are many more stakeholders involved in sustainability. Fig. 2 comes from an analysis at province level, showing stakeholders as circles of influence. Some examples are housing cooperatives and associations, electricity and gas suppliers and network providers, a wide range of commercial players from contractors and installers to financial consultants, and inhabitants, visitors, and local SMEs and entrepreneurs.

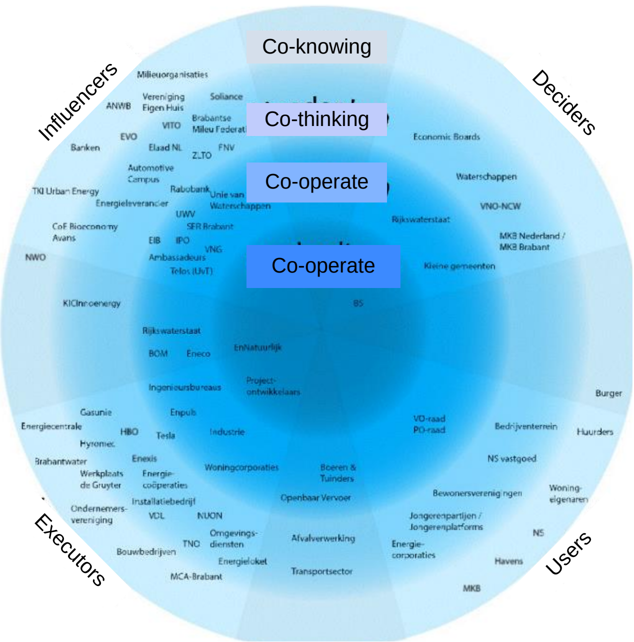

Fig. 2. Circles of influence from “Energiedoelstellingen Brabant 2030”, https://www.brabant.nl/politiek-en-bestuur/provinciale-staten/vergaderingen-ps/download.aspx?qvi=907893

C. *The Systems-of-Systems Perspective*

Sustainability plays a role through many layers of systems that interact in many ways:

- At micro-level, we have systems at individual houses, such as HVAC, electrical devices from lighting to housekeeping. Renewable energy adds PV-installations, and possibly energy storage.
- At meso-level, we have various types of infrastructure, such as transportation, energy generation, transportation and distribution, water and wastewater treatment and management, lighting, garbage collection, etc. Local PV-farms are emerging.
- At macro-level, the infrastructure takes the form of interconnected networks, such as the electric grid and the natural gas network and storage.

The energy transition to reduce CO_2 requires adaptations at all levels. For example, the transition from fossil fuel, especially natural gas, to renewable sources such as solar affects micro-level HVAC systems, and house insulation. However, the transition requires re-sizing of various infrastructure components at meso- and macro-level too. Advanced control systems need to ensure stable and efficient operation at all levels. Financial and legal systems come into play facilitating behavior incentives, such as load balancing, and demand management.

D. *Roadmapping as Facilitating Tool*

Roadmapping is a tool that businesses have been using for decades [3] [4]. A roadmap visualizes the strategy at a conceptual level so that it is compact and provides overview. Roadmaps typically have multiple layers, capturing the “Why?”, “What?”, and “How?” [4]. The process of making roadmaps requires ideation, exploration and analysis, synthesis, and visualization, packaging and communication. This process facilitates a wide variety of stakeholders to come to a shared understanding of what the future may look like, and how we may migrate from today’s situation to a desired future situation.

Fig. 3 shows an adaptation of the roadmap layers in [4] to sustainability. This adaptation transforms the tool from a business tool to a societal tool.

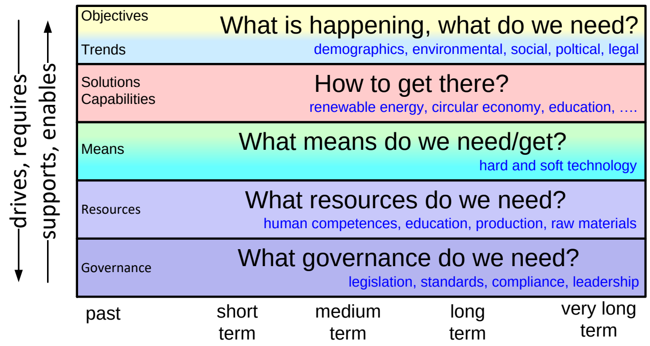

Fig. 3. Roadmap layers for sustainability roadmapping

The value of the roadmap has to appear when the stakeholders start using the roadmap. Fig. 4 shows how each organization may use the roadmap to develop a master plan. The roadmap is a shared vision that serves as context for the master plans. Each organization commits to master plan that they develop.

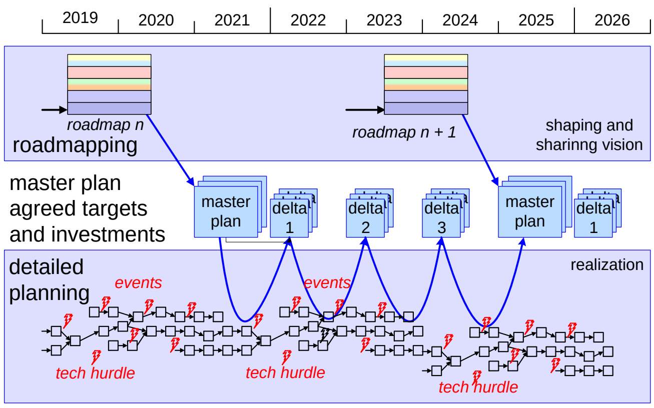

Fig. 4. Using the roadmap to develop master plans, which are the starting point for project plans.

The master plan sets targets and allocates resources to realize the targets. Within the scope of the master plan, organizations can define projects with their project plans. In practice, project plans have their own dynamics, due to internal and external factors, such as technical hurdles, resource surprises, and external events. A good master plan is more stable. However, since both projects and the external world evolve, it is good practice to have regular master plan updates. In the business environment, these updates are called quarterly rolling forecasts.

E. Case Study Research Project

In September 2018, the study program floated the idea to a student in industrial economy and systems engineering at the University of South-Eastern Norway to do her master project on the topic of Roadmapping for sustainability for Best Duurzaam. The result is a master project proposal for the municipality Best and Best Duurzaam with a preparation phase, an action research phase, and an academic closure. The municipality and all the involved stakeholders will continue after the Action research with a project to transform the roadmap into master plans and project plans, as shown in Fig. 4.

II. PHASE 0, A QUICK EXPLORATION

In the preparation phase, we made a quick exploration of the problem and solution options. We will briefly describe the current local situation, and the technical options for energy harvesting, heating, and other related technical aspects. Then we combine this information in a back-of-the-envelope estimate, to get a feel for the size of the problem and the economic impact of potential solutions. We conclude this section with some social and political considerations. A major concern of the entire sustainability transition is societal acceptance; technical feasibility and economic viability are not sufficient to make the transition.

A. The Current Situation

Fig. 5 shows the territory of the municipality Best and its neighborhoods. We color-coded the residential neighborhoods to show when the neighborhoods have been built approximately.

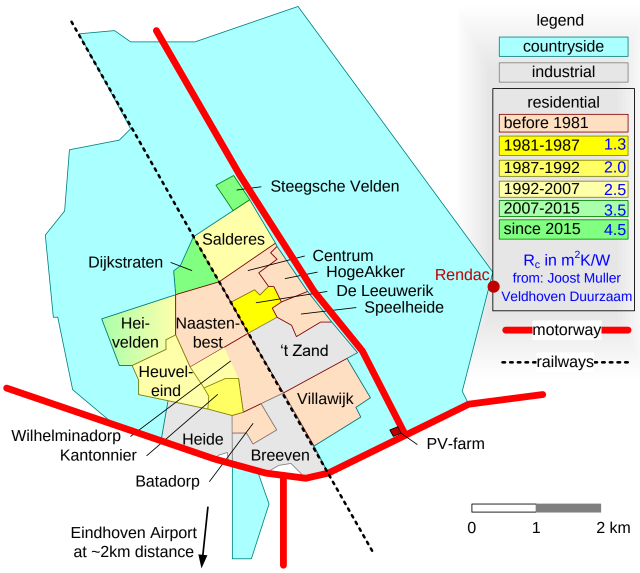

Fig. 5. The territory of Best and its neighborhoods.

The age of houses corresponds with the degree of insulation. The government has increased insulation demands via the building regulations. The figure shows the thermal resistance, the R-value, from the regulations per period. In theory, the amount of energy required for heating is reverse proportional with this R-value.

Most houses in Best are built in blocks. A typical house has 1 or 2 floors, a loft, a garden and left and right neighbors. In newer neighborhoods and the town center, we see an increasing number of apartment buildings. Of these houses, 72% are privately owned, housing cooperatives own and rent 20% of the houses, and the remaining 8% are other forms of rental houses[vii].

B. Technical Options for Energy harvesting

The town's ambition is to become energy neutral. There are several options for energy harvesting to achieve such neutrality. In the Dutch climate, there is a significant heating demand in the winter. At the same time, the solar potential in wintertime is much smaller than in summer time. In this first exploration, we ignore demand and supply variations.

1) Small scale PV

Most privately owned houses have room for 20 to 26 m^2 solar panels, which corresponds with 3 to 5 kWh/yr energy production. This covers the current average electricity consumption of privately owned house (3.7 kWh/yr), without heating, hot tap water, and cooking.

Commercial and industrial buildings have good opportunities for solar PV as well. Rental houses and apartments have some opportunity for solar. However, ownership and regulations complicate actual use of this option.

2) Large scale PV

In industrial and agricultural areas, there are some options for larger scale solar. Best has one large-scale solar installation, operational in 2019, that is privately owned. Inhabitants from Best are participating in a cooperative solar farm close to the airport (e.g. outside Best territory).

3) Agricultural options (Biogas)

Most countryside is agricultural with some pig farms. These pig farms may offer an option for small-scale biogas. Other bio mass options are rather limited.

4) Wind power

The close proximity of Eindhoven Airport prohibits wind turbines in nearly the entire territory. May be the ultimate northern part offers options for a wind turbine. Alternative options are to cooperate with neighboring municipalities or to use small wind turbines.

5) Industrial rest heat

There are few heat-producing industries in Best. A cadaver processing plant at the boundary with municipality Son does produce a significant amount of heat, besides biomass that is used for energy generation. A question is whether it is economically feasible to transport this heat over 3km distance

C. Technical Options for heating

Best has only a few options to replace the current heating using natural gas. The current average natural gas usage per house is 1430 m^3, which corresponds to about 13 MWh/yr.

1) Heat pumps

Heat pumps seem to be the most probable alternative. Assuming a COP of about 3.5, heat pumps would need about 3.7 MWh/yr replacing 1430m^3 gas.

There are many variants of heat pumps:

- Water-water heat pumps using water at depth of tens or hundreds of meters. The water authorities regulate the depth that pumps may use, e.g. to 80m. Water at greater depth is warmer and improves the COP. Alternative is using surface or ground water.

- Air-water heat pumps that can generate water for heating and hot tap water. Heating with ~35^{0}C results of COPs of 4 or higher. However, most existing houses have heating systems that require warmer water.
- Air-air heat pumps are rather efficient with COP values above 4.

A dominating concern when using heat pumps is the acoustic noise. The most expensive modern heat pumps produce about 50DbA. Regulations are not yet mature; in general, a noise level at neighboring facades of 30 0r 35 DbA is considered acceptable.

2) Heat network

When large residual heat capacity is available anywhere, then a heat network transports and distributes the heat to individual houses. Main challenge is to make the network efficient, e.g. minimize pumping and heat losses.

3) Renewable gas (Bio gas, SynGas)

The Netherlands has a well-developed gas infrastructure with en economic life of tens of years. Any way that produces gas from non-fossil sources can benefit from the existing infrastructure. This option may co-exist and complement heat pumps in so-called bivalent systems. In bivalent systems, heat pumps do the heating when outside conditions are good, e.g. resulting in high COP values. In the few cold periods (days to weeks in the Netherlands), gas heating takes over beating het pumps economically.

D. Other technical options

1) Insulation

In any scenario, insulation is the first step to consider. The Return on Investment for insulation tends to be short (months to years). However, good insulation increases feasibility of heat pump solutions. It can make the difference between expensive and affordable heat pumps.

2) Reduction of energy consumption

Similarly, most options for energy consumption are economic no-brainers. Using LED for lighting, and replacing refrigerators, washing machines, etc. with modern low-energy devices can half the electric energy consumption of households.

E. Back-of-the-envelope Cost estimate

To get a feel for the size of the transition, we make a coarse estimate of the total cost for this transition, using 2018 data. Fig. 6 shows this cost estimate. The estimate assumes that each house needs insulation, which is a prerequisite for heat pump feasibility. We add a solar PV system of 16 panels. The solar capacity is not yet sufficient to cover standard electricity use plus heating, which in average requires 3.7+3.7=7.4 MWh/yr. This solar system will probably produce about 5 MWh/yr maximum.

These coarse estimates use 2018 quotations from installers for solar and heat pump installations. Note that all of these data depend on local circumstances; variations may exceed +/- 50%.

Total cost per house adds up to 30k€. The cost for the entire town adds up to 360M€. To put these numbers into perspective, we compare the cost per house to the average yearly income of 26 k€/yr. We can also compare it to the average house value (according to the tax office) of 265 k€. Both comparisons show that such transition in average seems affordable, although costly. However, it may be a problem for people with less income. Another comparison it to the total budget of the municipality of 73 M€ for 2018[viii], compared to a total cost of 360M€.

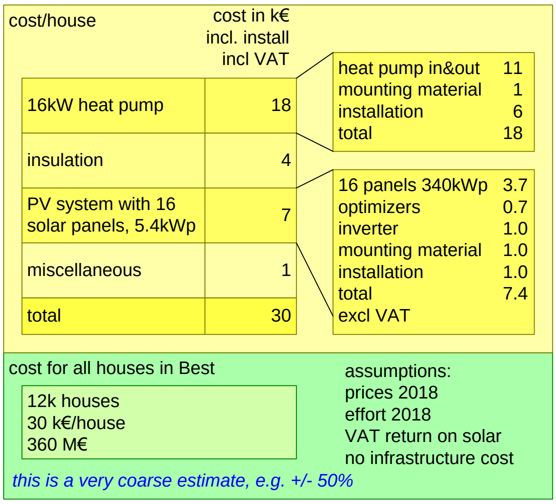

Fig. 6. Back-of-the-envelope cost estimate

F. Simplified Heat Transition Scenario

The core technology for heating is most probably heat pumps. Since the Netherlands has little experience with this technology, we elaborated the back-of-the-envelope estimate into a scenario. Elaboration of such scenario is a step toward a roadmap. The scenario uses the same layers as a roadmap.

Fig. 7 shows a simplified heat transition scenario, with a focus on the heat pumps. In the scenario, we target 45% CO_2 reduction medium term (e.g. ~2030 as stated in the IPCC report), and 100% long term. In 2019, we have 12 thousand houses, which will grow some more over the years.

The main purpose of making the transition scenario is to explore the playing field. In this way, we hope that we learn what questions to ask, what problems to explore, what relations need analysis. Many numbers in the scenario are assumptions without much underlying support.

For example, the price erosion of the hardware is 5% per year in the first decade and then gradually lowers to 2% per year. It will be clear that such choice has significant impact on the scenario. With cost reduction similar to the solar market, e.g. 70% from 2010 to 2017 [5], the transition would become much easier.

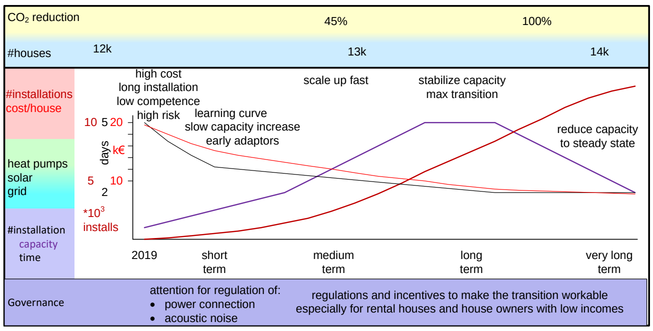

Fig. 7. A simplified heat transition scenario for Best.

Assuming that we replace all gas heating with heat pumps, we need to migrate all 12.000 houses in the coming decades.

Taking the renewable energy target, we should strive to migrate nearly half of the houses in the coming decade.

This migration hits a number of challenges:

- The cost price per installation is still high; this may lower when we go through a learning curve and achieve an economy of scale. Fig. 6 uses a few assumptions of the cost development of hardware and installations
- Best has few installers with heat pump experience. Growing this competence takes time. The scenario proposes a slow growth initially, and once we have critical mass and experience an accelerated growth.
- When the migration is near completion, we need a viable number of heat pump installers. Consequently, we first grow many installers and then have to scale back to a steady state for maintenance, replacement, and new houses.
- The limited experience translates in long duration per installation. The scenario assumes that the duration can reduce from one week initially to 2 days.
- These assumptions together result in only ~25% houses that are migrated in one decade. The expected cost reduction per house is more than a factor 2. In the short term, mostly the early adaptors will migrate.

The government bodies have to ensure proper regulations. For heat pumps, attention points are the acoustic noise, and the electrical connection power per house. Existing houses have connection points that may be limited to single phase 16A up to 3-phase 25A per phase. Current pricing for heavier connections are excessive.

Longer term, we need incentives for house owners for the migration, and a financing strategy. Especially for rental houses and house owners with a low income, this is essential.

G. *Social and Political Considerations*

From technical and macro-economic perspective, the heat transition is feasible (although there are plenty of challenges). The biggest hurdle is the acceptance and the motivation for all inhabitants. Inhabitants with the financial capacity may easily have incentives for the transition. However, inhabitants without the financial means get into a near impossible squeeze: increasing gas and electricity prices eroding their financial position further. In today's political climate, we suffer from ignorance and emotional blocking factors, as the yellow vests in various European countries illustrate.

These considerations translate into the need to include social, political, and economic measures into a roadmap, such that we can cope with them.

III. Phase 1, Action Research: Creating a Roadmap

The real work of creating a roadmap can now start. The researchers will participate in the creation of the roadmap, using the roadmap creation as action research vehicle. Fig. 8 shows the approach to the research project. Since societal support is a critical success factor, identifying, understanding, and involving stakeholders is crucial. Given the complexity of the topic, scoping is critical, which we do by exploring problems and solutions. Iteration over these activities and the actual roadmap will result in a final roadmap.

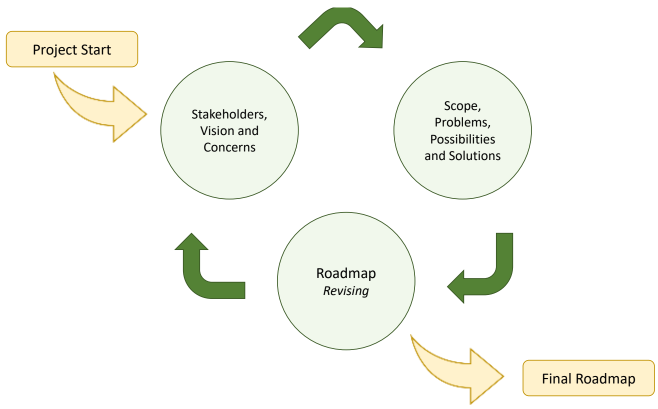

Fig. 8. Roadmap creation project

Fig. 9 shows the timeline for the roadmap development, showing that the project develops roadmap layers top-down with iterations over the layers. The total elapsed time for the development is 22 weeks.

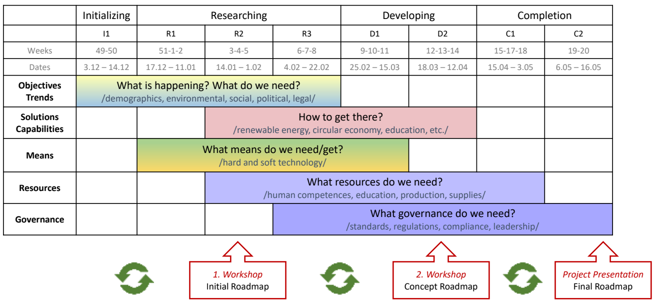

Fig. 9. Timeline for the roadmap creation

The researchers will observe while creating and use surveys to assess the value of the roadmap creation process.

At the moment of writing this paper, we have performed many interviews and two workshops. The second workshop started with the notes in the top 3 layers plus a set of A3s[ix]. Fig. 10 shows the results of the second workshop. All notes are input to the roadmap. Challenge is to select and order all inputs into an understandable and shared vision.

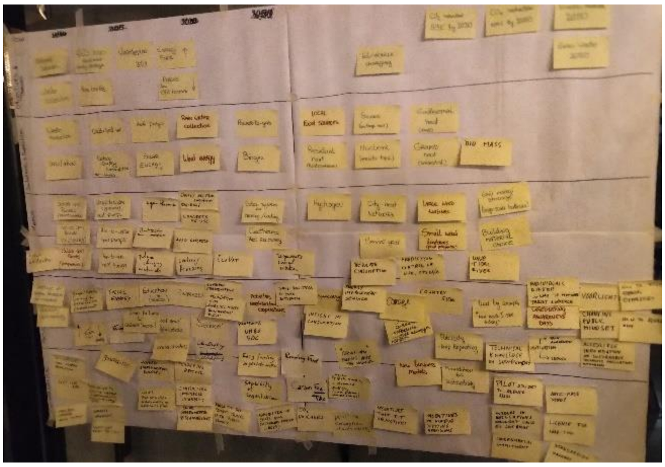

Fig. 10. Results of the second workshop

IV. Phase 2, Using and Maintaining a Roadmap

The plan is to involve most relevant stakeholders in the creation process in such way, that they are willing to keep the roadmap alive after its creation. Current idea is to create a steering group with representatives of these most relevant stakeholders that provide input to the creation process and monitor the creation.

We view the process of involving stakeholders in the steering group as a critical success factor, since the sharing and communication of ideas is an essential value of the roadmap creation.

V. Discussion and Reflection

As preparation for the workshop creation, we collected data and literature. We used these data for a back-of-the-envelope cost estimate and for a scenario. Main purpose is to get an understanding of the problems and potential solutions.

The scenario is missing the IPCC target of 45% CO_2 reduction in 2030 significantly; the replacement of fossil fuel (natural gas) by (sustainable generated) electricity for heating is 25% only. This outcome triggers new questions how we can accelerate the transition, or how we can compensate the surplus of CO_2 in another way. For instance, any investment in insulation will reduce CO_2 immediately.

The insulation prerequisite does trigger another set of questions that we ignored in the simple scenario: what do we do with houses that have a construction that barely allows insulation? Some of the older neighborhoods of Best have many houses where sufficient insulation may be impossible or rather costly. From economic perspective, demolishing and rebuilding is the rational approach. However, from inhabitant perspective this may be a rather traumatic experience. These neighborhoods may require a specific strategy to rebuild blocks of houses when the opportunity arises.

The scenario ignored infrastructural prerequisites. The amount of electricity on the network may triple or worse when we replace natural gas by electric heating. The lead-time for infrastructure updates is many years. Here a roadmap helps to start such expansion and its financing timely. The scenario also ignored the need to generate sufficient electricity. The amount of solar PV in the cost estimate is insufficient to cover heating.

We entirely ignored variations in demand and supply of electricity, with the seasonal variations as the most dominant. Many studies [6] show that the grid plays an essential role in coping with these variations. The larger the grid and the more diverse the sources of energy, the lower any storage demands are. That suggests that only limited storage is required at local level; coping with demand and supply variations is handled better at meso and macro level.

The scenario shows the need for a tenfold increase in installation capacity. In today's market, we see a structural shortage of people with prerequisite education for this type of technical job. Therefore, it not just a matter of creating training and jobs. Somehow, we also somehow need to motivate people to choose the prerequisite education.

The format with interviews and workshops generated many inputs, as can be seen in Fig. 10. We foresee a presentation of the first phase on May 15, 2019. We expect an initial roadmap with some significant questions that we need to address in the next pahse.

VI. Conclusions

The coarse cost estimate and the simplified heat transition scenario triggered many questions, and helped us to gain insight in factors and relations that deserve further exploration.

Acknowledgment

Many people, e.g. volunteers from Best Duurzaam and Veldhoven Duurzaam, and local installers of heat pumps and Solar panels supported the collection of initial data. We look forward to work further with them and many more stakeholders in the next phases of the Roadmapping project.

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