

Article

# Applying Roadmapping and Conceptual Modeling to the Energy Transition: A Local Case Study

Gerrit Muller 

Faculty of Technology, Natural Sciences and Maritime Sciences, Campus Kongsberg, University of South-Eastern Norway, Kongsberg 3613, Norway; Gerrit.muller@usn.no

**Abstract:** The climate crisis requires a global transition toward sustainable practices. In this transition, policy makers face the challenge to take along a wide variety of stakeholders with own interests, needs, and concerns. This research explores the combined use of conceptual models and roadmapping to facilitate understanding, communication, reasoning, and decision-making between a large heterogeneous set of stakeholders. We apply these methods, in the form of action research, in several smaller research projects at a small town in the Netherlands. We find that the combination of conceptual modeling and roadmapping facilitates discussions between heterogeneous stakeholders on complex transition problems, such as the energy transition, at a local scale. However, we see a significant gap in the way of thinking and communicating between experts and decision-makers, which requires additional means to connect them.

**Keywords:** roadmapping; energy transition; sustainability; conceptual modeling



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## 1. Introduction

In this paper, we study methods and techniques from the systems engineering domain to cope with the tremendous complexity of the global challenge of the energy transition. We build upon [1], that proposes the use of roadmapping as a method for analyzing the sustainability transition at the local level and using conceptual modeling to support shared understanding, communication, and reasoning about options.

Phaal et al. [2] propose roadmapping to provide a temporal overview, e.g., from the past to the long-term future. Conceptual models are models that are simple enough to promote shared understanding and communication and, at the same time, substantial enough to create meaning and value. Conceptual modeling builds upon a way of working from various disciplines, such as simulation [3,4], soft systems methodology [5], collaborative working [6], and systems engineering [7].

The sustainability transition is a global scale challenge that relies upon every available human expertise. The United Nations have defined 17 Sustainability Development Goals (SDGs) [8] as an organizing framework. A systems engineering perspective suggests many factors that make the SDGs and the energy transition so challenging:

- Earth as natural system
- The Systems of Systems (SoS) characteristics
- Many solutions need inventing, e.g., they are unknown or uncertain
- The scope is broader than sociotechnical
- The global variety of stakeholders.

The International Council of Systems Engineering (INCOSE) [9] states,

Systems Engineering is a *transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.*

“We use the terms “engineering” and “engineered” in their **widest sense**: “the action of working artfully to bring something about.” “**Engineered systems**” may be composed of any or all of people, products, services, information, processes, and natural elements.

This paper explores and illustrates systems engineering methods that support building (shared) understanding, communication, and reasoning for complex problems, using roadmapping and conceptual modeling to address the challenges of the energy transition.

The goal of this research is to find ways to support society in dealing with these transition challenges and to accelerate the sluggish transition. The research questions that addressed in this paper are as follows:

- RQ1. How can we help a heterogeneous set of stakeholders to formulate a shared understanding of the current situation and of the options and their consequences to resolve them?
- RQ2. How can a shared understanding help in reasoning about the solutions and, in that way, help in decision-making and preparing governance?
- RQ3. What is a manageable set of conceptual models to achieve understanding, reasoning, communicating, and decision-making?

The research design is that we apply these methods at a local level, e.g., a town of 30 thousand inhabitants, rather than at national level (e.g., tens of millions of inhabitants) or global level (billions of humans). We hope to gain insights from using the methods on a smaller scale that may help to address the even more complex transition at national and global levels and apply the insights to the SDG framework.

The contribution of this paper is the combined use of roadmapping and conceptual modeling and their application in a societal context toward the energy transition, as part of the sustainability transition.

The paper continues with background on the sustainability and energy transition in general and the challenges in addressing these transitions, followed by a brief description of the town that we used in the case. The next section provides the theory behind roadmapping and conceptual modeling. The materials and methods section discusses the research design. In the results section, we show various results achieved so far. Finally, we discuss the progress of the municipality toward the sustainability transition and the findings related to the research questions.

### *1.1. The Global Sustainability Challenge*

The United Nations provides a scientific framework through the Intergovernmental Panel on Climate Change (IPCC) and a sociopolitical framework through the SDGs and the Paris agreement. The IPCC relates the climate insights in [10] to the SDGs, and it links the specific needs for the energy transitions with the SDGs. A core message is that humanity must reduce the CO<sub>2</sub> (and greenhouse gasses overall) to zero emissions by 2050 to stay at 1.5 °C temperature rise, as agreed in the Paris agreement [11]. The SDG framework sets the broader sustainability context for the energy transition.

### *1.2. What Makes the Energy Transition So Challenging*

Earth is a natural system with complex properties and behavior. Even an organization like the IPCC, with many well-respected scientists, does not claim a complete understanding of our own planet.

The energy system is a System of System (SoS) to the power of n. Maier [12] defines SoSs as having managerial independence, operational independence, geographic separation, emergent behavior, and evolutionary development. Interestingly, constituent systems of the energy system have no full operational independence in the current grid architecture; however, they fulfill all other SoS characteristics. The energy system has many layers of systems, from (inter)continental grids, national grids with its power sources and controls, regional and local grids, individual buildings, and other platforms, down to personal power producing or consuming devices. The technologies and constituent systems of the

energy system of the future are still under development or, worse, not yet invented. The 2050 target date is probably beyond most people's horizon.

The energy system is sociotechnical, with all the dimensions, political, economic, social, technical, environmental, and legal (PESTEL) [13] having relevance. Heleen de Coninck, one of the main authors of the IPCC report SR1.5 [14], states in [15], "Technologies are always part of a cultural, social, economic, legal, and policy-based system. With a fundamental change in the energy system, they also change with it. Or maybe they even have to change first to make the technological change possible."

Lastly, the number of stakeholders is huge, as is their variety of roles, power, and knowledge. The stakeholder field is complex, due to the psychosocial and political nature of humans. Perceptions, emotions, personal, organization, and national interests make the problem domain more complex than the field of engineered systems, where systems engineering originates.

### 1.3. Introduction to the Town Best, Where the Research Takes Place

The approach of this research is to use action research to apply roadmapping and conceptual modeling at a local scale on specific parts of the energy transition. We will report on an initial roadmap and set of conceptual models that we made for the town named Best in the South of the Netherlands; see Figure 1. Best has about 30 thousand inhabitants. It is a town and municipality with a council and several aldermen as administration. For the energy strategy, Best is part of the metropolitan region Eindhoven [16]. In turn, the metropolitan region is part of the province Noord Brabant.

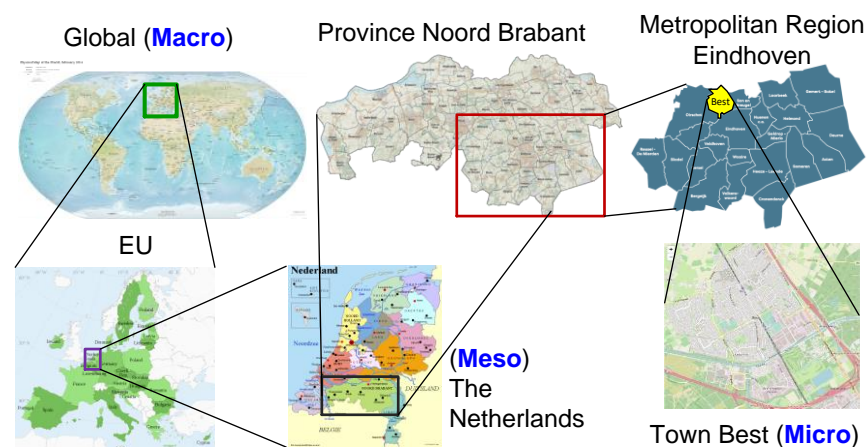


Figure 1. Best in Noord Brabant in the south of the Netherlands.

## 2. Methods from Systems Engineering

### 2.1. Theory of Roadmapping

Phaal [2] provides the basic framework of roadmaps with a horizontal timeline spanning short-term, medium-term, long-term, and vision. Vertical layers define why, what, and how. The more specific guidelines for sustainability roadmaps [17] explicitly add policy instruments and governance in the how layer. Figure 2 shows the starting point of the roadmapping based on [2,17].

Roadmapping is a well-researched field. Phaal [18] maintains a bibliography with over 1100 references. The website <https://www.cambridgeroadmapping.net/> (accessed on 20 March 2021) provides examples, templates, research, and experiences of roadmapping over a broad set of domains, including global applications and organizations, such as the International Energy Agency (IEA) in the energy sector and United Nations organizations, such as the United Nations Framework Convention on Climate Change (UNFCCC) [19] and United Nations Industrial Development Organization (UNIDO) [20]. The UNIDO report [20] uses Foresight as another common name for methods to envision the future.

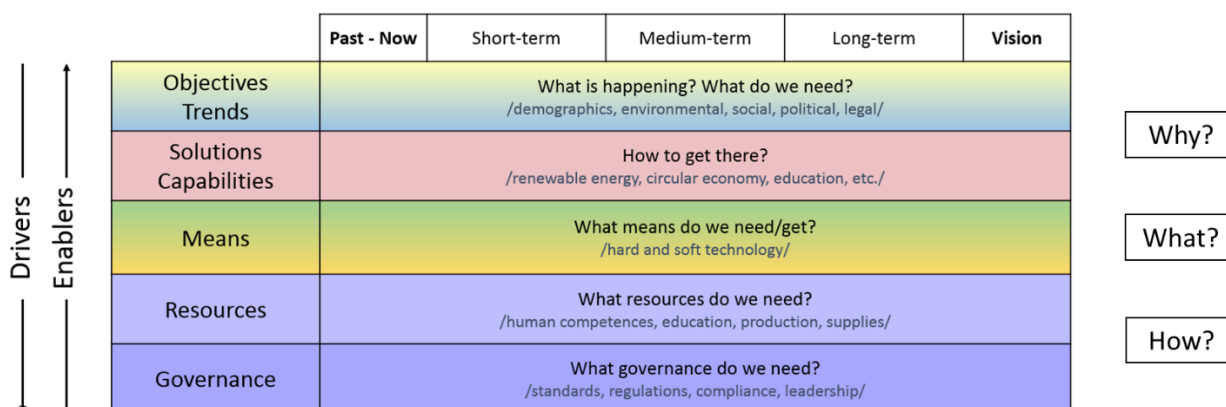


Figure 2. A 5-layer Roadmap Model.

## 2.2. Theory of Conceptual Modeling

Conceptual modeling has multiple origins, e.g., physics, for development of simulations, as a means for collaborative working, or as means for conceptual design in systems engineering. The common denominator between these various origins is the value of concepts to facilitate communication and thinking. In this subsection, we will discuss some of these origins.

There is a broad field of methods in *collaborative working* that use conceptual modeling more or less explicitly:

- Design Thinking [21], with a heavy emphasis on human interactions.
- Gigamapping, originating in systems-oriented design [22], employs many kinds of visualizations on a so-called gigamap to enhance communication. Gigamapping relates to design thinking in its interaction style.
- Neely et al. [6] propose collaborative conceptual modelling as a tool for transdisciplinarity. The workshops that this method [23] proposes are quite similar to gigamapping.

The field of simulations also provides much literature on conceptual modeling. Sargent [24] defines conceptual models as “the mathematical/logical/graphical representation (mimic) of the problem entity developed for a particular study.” Many authors, e.g., [3,25,26] relate the use of conceptual models to simulation. Robinson [3,4] asserts, “It is almost certainly the most important aspect of a simulation project,” and “conceptual modelling is more of an ‘art’ than a ‘science’ . . . .”

In the systems engineering field, there are many forms of conceptual modeling, as the various engineering disciplines all use their domain-specific conceptual models. Blanchard and Fabrycky [7] cover a wide variety of (conceptual) models. Tomita et al. [27] discuss the conceptual system design and propose to apply design thinking to lift the discussion from data and information level to knowledge and wisdom level. Montevechi and Friend [26] propose the use of *Soft Systems Methodology* (SSM) [5] in developing conceptual models. In the context of the energy transition, which is a challenge across technology, economy, society, and environment, the use of SSM makes a lot of sense. *Systems Thinking* is an essential competence when developing conceptual models. For example, Jackson [28] links systems thinking to address highly complex problems.

In this paper, we build on the author’s earlier work [29]. Conceptual models bridge the first principle and empirical worlds. Empirical models provide a means to capture what we observe and measure without an understanding of what we observed. First-principle models are models that use the theoretical principles from science, such as the laws of physics, to explain the behavior of a property using the first principles. These models often take the form of mathematical equations and formulas. When we enter values in the formulas, then we can compute the resulting property for these values. A conceptual model explains observations and measurements using a selection of first principles. A conceptual

model is a hybrid of empirical and first-principle models. It needs to be simple enough to understand and to reason, while it must be realistic enough to make sense.

### 3. Materials and Methods

A major challenge in researching these transdisciplinary problems is the number of relevant disciplines, each with its own frameworks and research methods. For instance, the research of heating options may require an understanding of thermodynamics, while the problem of acceptance by inhabitants requires social sciences.

Given the urgency and importance of the energy transition problem, this research adopts a pragmatic approach. First, we limit the research to a single, small, town. Next, we decompose the research into smaller research projects with a limited scope, such that the smaller research project can apply the specific research method suitable to the nature of that research topic.

The main research method is action research [30], all conducted in the context of this town. Each researcher visited the town and had access to the stakeholders and was given the opportunity to explore and test their findings in this real-world situation. The research took place in steps:

1. Preparation and project definition with the local stakeholders [31]
2. Creating the initial roadmap in cooperation with the local stakeholders [1,32]
3. Creating and operating a task force of representative stakeholders that discusses, maintains, and operationalizes the roadmap
4. Further studies of specific aspects of the roadmap (not yet published)
5. Continuous observations of the local situation

Steps 3 and 4 partially overlapped with the Covid-19 pandemic situation, which clearly affects the research, since the interaction with stakeholders was quite different.

The principal investigator is an inhabitant of this town and member of the sustainability cooperation. The other researchers came from outside the town and, in some instances, from outside the country. The double role of the principal researcher is clearly a dilemma in the research design. Benefits of such close ties are:

- The in-depth knowledge of the local situation.
- The access to relevant stakeholders.
- The a priori overview of the local situation.

Risks of such close ties are:

- Lack of objectivity.
- Bias from relations or from personal opinions and beliefs.
- Pressure from inhabitant stakeholders.

These risks exist for action research anyway [33], but the double role may exacerbate them. We expect that the benefits outweigh the risks. However, we acknowledge that the validity of the research is limited by this choice. The validity of this research is therefore limited in many directions. Generalizations are not possible, but the combined findings and methods applied offer insight for researchers in the domain.

### 4. Results

#### 4.1. Step 2. Creating the Initial Roadmap

Laura Elvebakk, who studied Industrial Economy at University of South-Eastern Norway in Kongsberg (USN), helped to create an initial sustainability roadmap for Best during her master project in 2019 [1]. Figure 3 shows her approach, where she alternated interviewing stakeholders and synthesizing results in workshops. The initial interviews and workshop focused on the two top layers of the roadmap (the why), e.g., objectives and trends and possible solutions and capabilities. The second set of interviews and workshops elaborated the next layers (the what and how), e.g., what are the means, resources, and governance that we need to create the solutions and capabilities to achieve the objectives



and cope with the trends? The time frames defined were short-term (2019–2021), medium-term (2022–2025), and long-term (2026–2030).

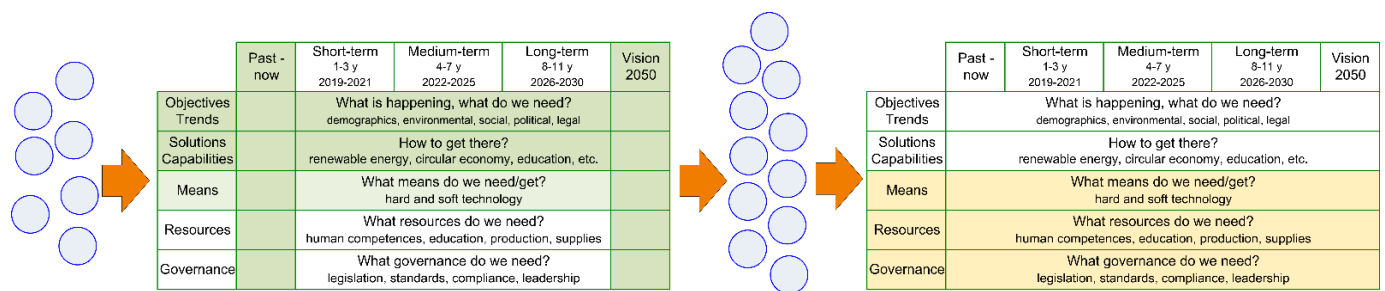


Figure 3. Interview and workshop progression [1].

The result was an initial roadmap as shown in Figure 4, and [32] discusses the roadmap contents. The main elements of the roadmap are

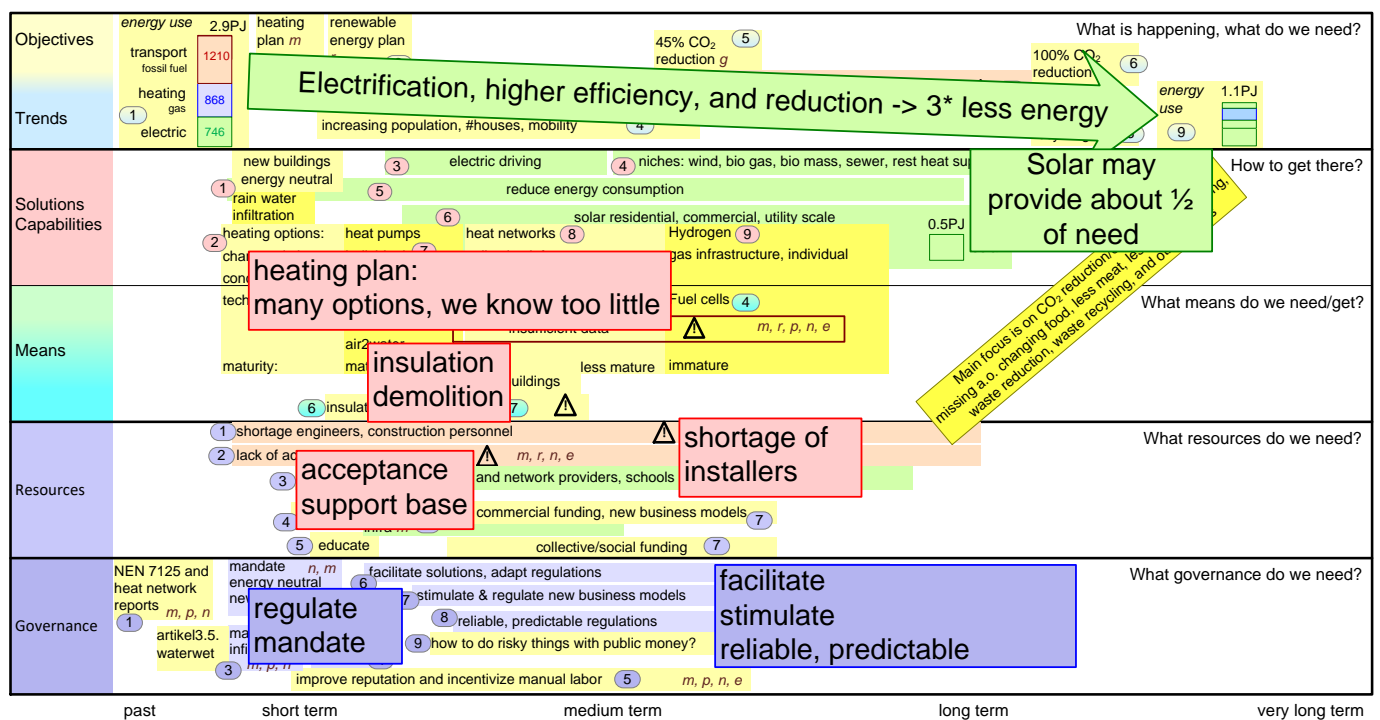


Figure 4. Summary of the initial Sustainability Roadmap for the town Best in the Netherlands [32]; the initial roadmap in A3 size is available at <https://gaudisite.nl/BDRA3initialRoadmapBest.pdf> (accessed on 20 March 2021).

- **Objectives and trends:** Reducing the current yearly energy consumption of about 3 PJ generated mostly with fossil fuels to about 1 PJ in the form of renewable sources and carriers.
- **Solutions and capabilities:** Using residential and industrial roofs, agricultural, and land close to motorways to install solar solutions will allow for the yearly generation of about 0.5 PJ. Other niche solutions may generate a fraction of solar. Main challenge is heating of buildings.
- **Means:** There are multiple technology options for heating, with rather varying degrees of maturity. An initial concept exploration is essential before the municipality can develop any meaningful policy. Obvious and urgent technologies that need policy and implementation are insulation and material choices (e.g., no concrete or traditional bricks) for buildings.

- **Resources:** A major bottleneck for execution of the transition is the installation and construction capacity of qualified installers. A major prerequisite is support of the population. Stakeholders see motivation and incentives as better instruments than force or fear.
- **Governance:** A main challenge is creating the legislation and conditions to implement the solutions in such way that stakeholders are involved and motivated. Stakeholders emphasize the need for facilitation (incentivizing) and (long-term) predictability.

One of the challenging steps of roadmapping is the collection and ordering of supporting information. The roadmap itself should be limited, e.g., one sheet with the five layers. However, each word in a roadmap is the result of an analysis and discussion using various data sources. Here, the conceptual modeling appears. We can capture the underlying information in a number of conceptual models at the back-of-the-envelope level or the A3 level.

Figure 5 shows an example from [32] with an estimate of the amount of solar that municipality Best can generate. It analyzes commercial, residential, utility scale, and countryside solar options using available surface areas. Although this is a rough estimate, it helps to know what is possible and how various options compare. In hindsight, the countryside estimate is too low, due to underestimating the size of farm buildings.

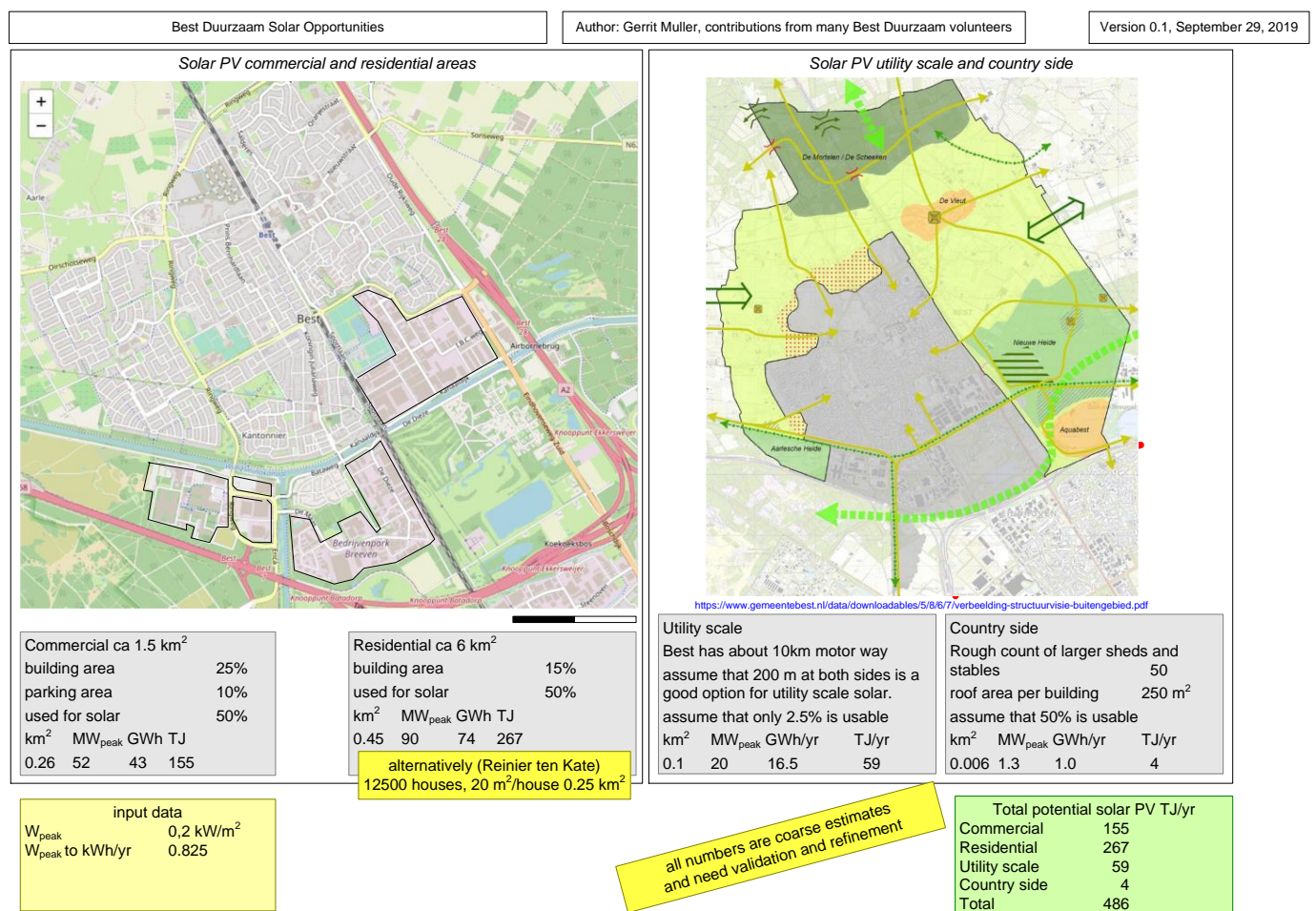


Figure 5. Example of underlying A3, elaborating how much solar Best can install [32].

#### 4.2. Step 3. Creating and Operating a Task Force

The municipality is the formal owner of the transition plans and has the responsibility and mandate to set the policy and transform that into legislation, within the charters of the national and regional governments. The cooperation Best Duurzaam is a volunteer organization with members. In the preparation phase of the roadmap, Best Duurzaam identified the need for a consultative body of stakeholders. It took these two rather different organizations more than a year to set up a task force consisting of representatives of organizations that are stakeholders in the transition.

The objective of this task force is to involve and align the stakeholders of the transition. The idea is that a roadmap is a shared vision. However, stakeholders are not yet committed to that vision. The commitment follows in the elaboration of the roadmap into master plans per organization. The task force exchanges the master plans and discusses them. Organizations may adapt their master plan based on these discussions.

The task force has met three times since the creation of the initial roadmap. The task force clearly is in its early infancy. Various representatives have to build up mutual trust and to find their roles. The number of participating organizations is still small (municipality, sustainability cooperation, primary and secondary education, building cooperation, and agriculture sector). The idea is to grow the task force gradually.

#### 4.3. Step 4. Further Studies

##### 4.3.1. Seasonal Energy Storage

Since the roadmap identified the main energy source as a solar solution and the main energy consumption as heating, the energy supply and demand are out of phase. In the summer, we can harvest much energy, while in the winter, we consume most energy. A question is, how we will cope with these seasonal differences?

At the national level, the Netherlands will harvest a significant amount of energy via offshore wind. There is more energy potential for offshore wind in winter than in summer. At the national level, there are other energy consumers, especially in industry, that use significant amounts of energy, more or less constantly. This means that coping with seasonal energy fluctuations at the national level is easier than at the local level.

Another of the USN Norwegian master students, Erik Drilen, studied various concepts for seasonal energy storage. He made conceptual models for the most promising options. Figure 6 shows an example of a conceptual model for Power-to-Gas (PtG) [34].

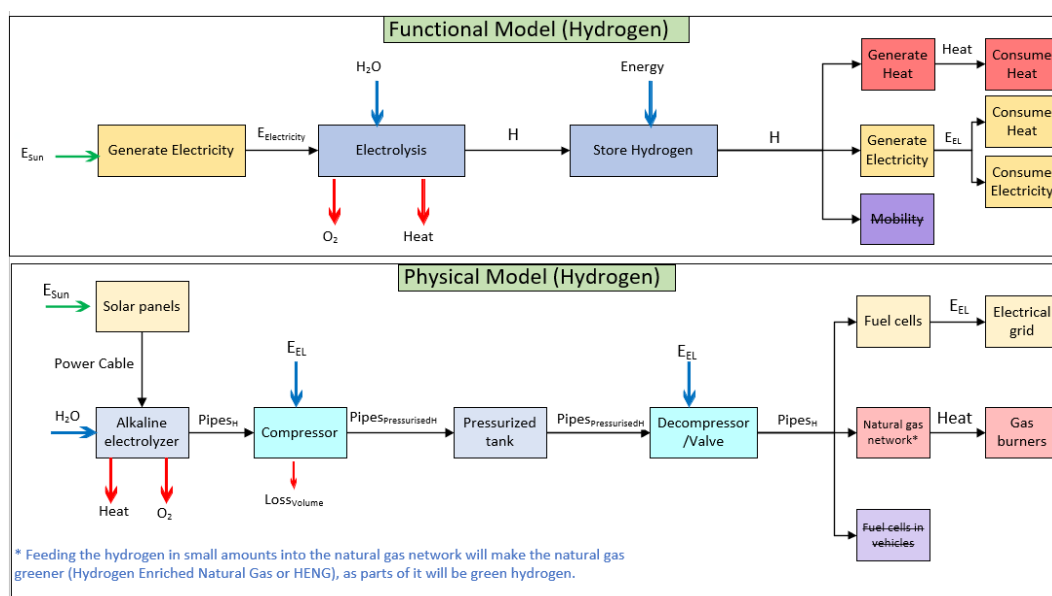


Figure 6. Power-to-Gas (PtG) functional and physical model. Reproduced with permission from [34].



Drilen then uses the functional and physical models to estimate the behavior and performance of the selected options. This estimate shows that a mostly electrified scenario using heat pumps is most energy efficient. The next step is that he uses that data to estimate the economic performance. These estimates indicate that storing the energy in the form of methane requires the least storage volume and has the lowest cost, despite the lowest end-to-end efficiency.

His paper ends with a reflection, which may be typical for conceptual modeling:

*“The steepest part of [the] leaning-curve was at the late stage of the project. At this point, I started to get a better understanding of the technologies and the consequences related to them. With the increasing knowledge came an increasing understanding of what was missing or what I should im-prove. A learning from this is that with more knowledge, comes more questions. This created a chaotic final stage of the project. As I ended up with many new questions that I had to answer in a short period.”*

#### 4.3.2. Support for Sustainability in the Population

Vince Evers, a student from the Department of Sustainable Energy Technology & Innovation Sciences at the Eindhoven University of Technology, did his internship at Best Duurzaam. In that period, he studied the research question, “What factors, psychological or otherwise, influence the acceptance of sustainability measures and projects among the key stakeholders in the municipality of Best, and how do these influence implementation?” The trigger for this study is that district heating is one of the dominating options; however, it is poorly received by the citizens [35].

He developed a framework for acceptance, see Figure 7, based on the literature, among others [36–39]. **Financial Costs and Benefits** are probably obvious concerns for most stakeholders. **Values and Goals** relate to personal norms, values, motivations, and goals. A perceived lack of **Justice and Participation** may result in opposition to sustainability [36,39]. **Trust and Communication** is a major issue, as contemporary headlines confirm [40]. Lack of (perceived) **Efficacy and Feasibility** is eroding acceptance.

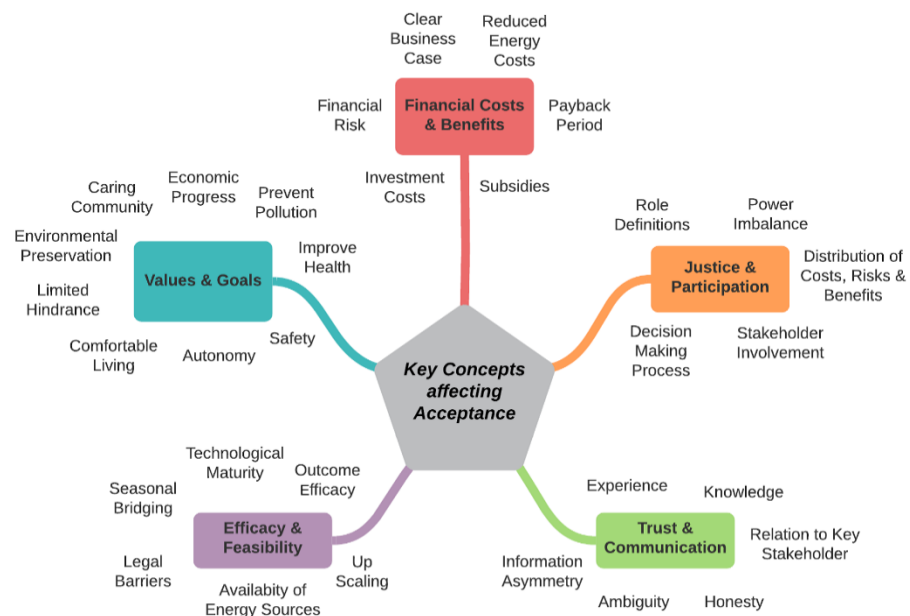
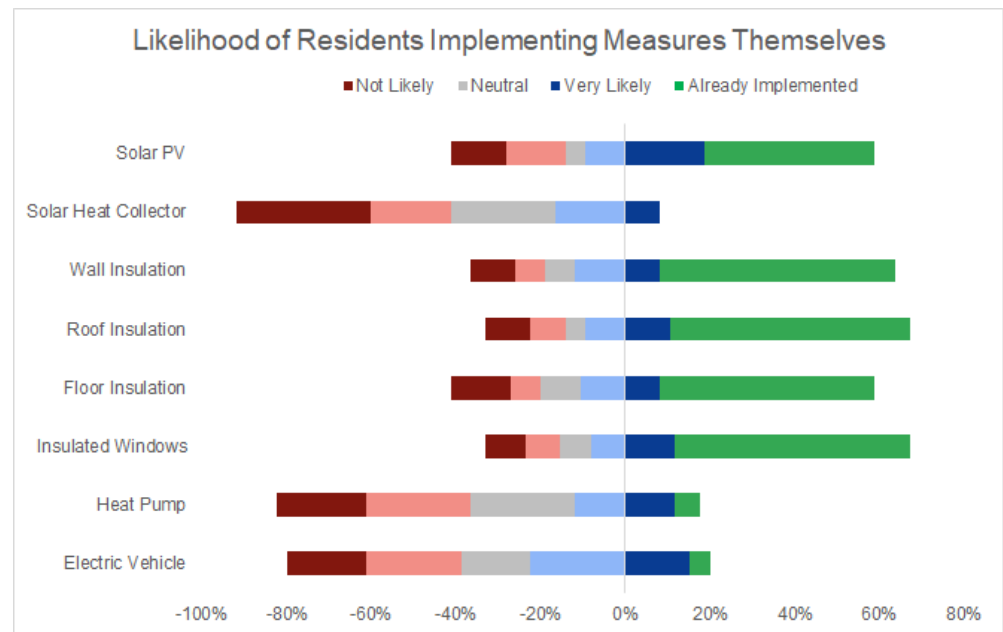


Figure 7. Conceptual framework for acceptance. Reproduced with permission from [35].

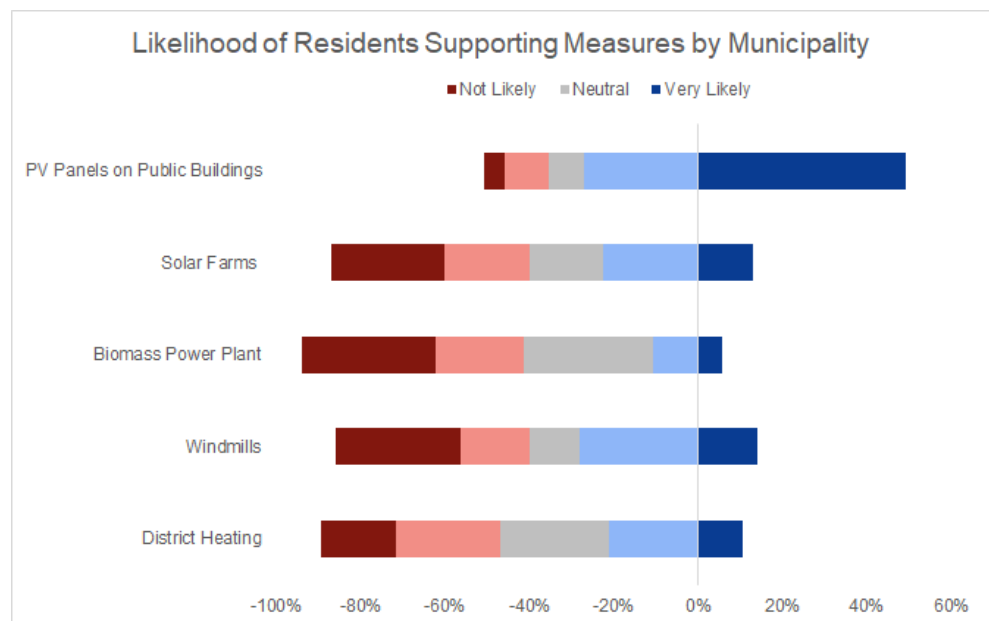
Figure 8 shows the results of a survey with 85 respondents. The centering of the bars is based on a net promoter score [41]. What is immediately clear is that “easy” measures, such as solar panels and insulation, are popular. These measures have a return on investments

of several years with the current incentive schemes. However, crucial electrification, like heat pumps and electric vehicles, are not popular yet.



**Figure 8.** Survey results for sustainability measures under residents of Best for individuals. Reproduced with permission from [35].

Figure 9 is a continuation of the same survey; however, these questions address measures that the municipality may take. Only PV panels on public buildings get a rather positive reception. All other measures trigger significant opposition.



**Figure 9.** Survey results for sustainability measures under residents of Best for municipality measures. Reproduced with permission from [35].

#### 4.4. Step 5. Continuous Observations of the Local Situation

One advantage of a co-located principal investigator is the possibility to collect continuous observations between research projects of events taking place in Best that relate to the roadmap.

##### a Heat storage in combination with solar collectors

The municipality developed a plan to harvest solar energy using solar collectors on the sport hall. The harvested heat would be stored in a large underground tank, and then several schools and the sport hall would use the stored heat for heating and hot tap water. Drivers behind the project were a high subsidy in solar collectors, a potential subsidy for frontrunner projects in heating, and the vision that local storage of heat would reduce the load on the electric network (when heating would change from using natural gas to using electricity). This plan was a mix of visionary aspects, such as using a fifth-generation heat network, and pragmatism, such as using planned maintenance of the sewer system to install a heat network in the streets.

The council rejected this plan, since its alignment with policy was unclear, while the financial risks were significant. The civil servants and the politicians who made this plan did not use the roadmap to explain how this project would help in achieving sustainability goals. The project preparation and discussion in the council were quite ad hoc.

##### b Municipality contribution for the 2030 renewable energy strategy

The process in the Netherlands to develop transition plans is highly distributed. There is a national agreement (“klimaatakkoord” [42]) that serves as a charter. Regions of tens of municipalities have to develop a Regional Energy Strategy. These regions ask the municipalities to make an “offer” of how much renewable energy they can produce in 2030. National government, regions, and municipalities then iterate until they have a fitting proposal. The alderman of municipality Best made an estimate very similar to the roadmap estimates to come to an offer. He consulted several stakeholders, including Best Duurzaam. This offer was in line with the roadmap.

##### c The request for commercial solar farms

Several commercial companies have proposed solar farms in Best. The national agreement states that half of the local renewable energy assets must be owned locally. There is a clear tension between the intent in the agreement of shared ownership to ensure support from the local population and commercial exploitation.

Concurrently with these proposals, the municipality was formulating the policy for environmental regulations. Best Duurzaam and several political parties pushed hard to ensure that the environmental regulations would not open the door for commercial exploitation without arranging how the shared ownership will work.

This is an example where “vertical” relations in the roadmap, in this case, solar farms as the solution, commercial companies and local population as resources, and environmental and exploitation regulations in governance, are coupled. A roadmap is a way to visualize such relations and to think of how to evolve to the desired state.

##### d Unrest in the countryside about the number of solar farms

The request from the regional energy board for a renewable energy offer triggered major unrest in the countryside. A news item on this offer suggested that a significant part of the countryside must be transformed into solar farms. Similar unrest played in other municipalities as well. An expert from a national university estimated solar on roofs can fulfill a significant part of such offer. However, the way the national system is set up more or less ignores small contributors. Hence, the risk is that, rather than using (unused) roofs, we would sacrifice agriculture or nature grounds. This is another example of lack of overview. The roadmap and its underlying conceptual models offer insight into what the options are and what the consequences of these options are.

## 5. Discussion

The discussion will first discuss how the constituent research projects affect the local sustainability efforts. Then, the discussion broadens to the larger scope, e.g., national and global. Finally, we discuss how the combined use of systems engineering methods roadmapping and conceptual modeling support the approach to the energy transition in the broader scope of the sustainability transition.

### 5.1. How the Research Projects Affect Local Sustainability Efforts

The 17 UN sustainability development goals articulate a significant global challenge. The energy transition, as part of them, is, in itself, a huge global challenge. We observe that, at national level in the Netherlands, there is an attempt to involve a wide variety of stakeholders. The so-called climate tables, where stakeholders discussed and negotiated how to achieve the energy transition, resulted in a national climate agreement. However, this agreement is a sociopolitical agreement, where the expertise of solving complex problems is missing. Many methods from systems engineering are useful in tackling this problem, especially roadmapping and conceptual modeling. In this research, in the limited scope of the municipality Best, we tried out several of the core methods to create an overview and to align a heterogeneous set of stakeholders.

We observed that most stakeholders were open for a constructive dialogue using a roadmap. However, we also observed that most stakeholders felt comfortable in their own niche (limited application scope, limited time horizon, concrete actions). Some of them were able and willing to connect their niche to the broader context. Other stakeholders preferred to do their own work, leaving the strategic work to others.

The municipality lacks systems engineering expertise. Most governmental organizations rely on external consultants for their expertise. In the heat storage case, the municipality had external expertise to make a design and a plan for the heat storage solution. The experts jumped at once to a feasibility study level without first exploring a range of options. Such exploration is required to understand the problem better, to analyze how solutions may fit, and to anticipate consequences.

The discussion and planning of solar farms shows the importance of providing overview and the need for communicating clearly. Estimating the required area for solar farms is relatively easy. However, the complexity of solar farms is in the socioeconomic model, which has impact on the support for such solar farms.

Although estimating the required area for solar is easy, we observed that current regulations trigger undesired rooftop sizing of solar. Residents get a good return on investment, as long as their production is similar to their consumption. However, over-consumption is not financially attractive. The consequence is that most people install “just enough” solar for their own consumption. In the wider perspective, we need to maximize solar on roofs, and to avoid that, we have to sacrifice agriculture or nature areas. Hence, we conclude that the current incentive scheme is counterproductive.

A recent news item [43] states that foreign investors own 79% of large Dutch solar farms. The subsidies to incentivize solar farms make solar farms rather attractive investments, rendering a yearly return up to 15%. This analysis makes clear that current legislation is not achieving the goals of the national agreement. Legislation at national and local level (e.g., environmental permitting) needs updating and alignment. This is a typical example of how roadmap layers connect.

The seasonal storage study illustrates how relatively simple conceptual models provide insight in strengths and weaknesses of various technology options. This type of modeling should take place before the municipality starts feasibility studies, such as the heat storage. We assert that the combination of roadmapping to set heat harvesting, storage, and distribution into a broader perspective and conceptual modeling to understand options and their impact will help to identify sensible options and to “sell” them to the council and other stakeholders. The acceptance study shows that securing support is a significant challenge, since the current opinion about such technologies is quite negative.

### 5.2. How Do These Methods Relate to the Broader Scope, e.g., National and Global?

Another future challenge is that we need similar methods and competence at the regional and national levels. Lack of overview and direction at these levels is frustrating the overview and alignment at local level. Moreover, solutions at the local level need scrutiny from regional and national (and European) levels. For instance, coping with seasonal variations is easier at national or European levels, since we then have more options to even out temporal and spatial variations.

### 5.3. How Does the Combination of Roadmapping and Conceptual Modeling Support the Approach to the Energy Transition?

This subsection addresses the research questions as far as the ongoing research allows this.

RQ1. How can we help a heterogeneous set of stakeholders to share an understanding of the current situation and of the options and their consequences to resolve them?

The conceptual models that the research used on A3s to build the initial roadmap helped in the stakeholder workshops. This is in line with [6,23]. These A3s helped in facilitating the stakeholders to have concrete and specific discussions in a problem field that is large and intangible.

Transferring these insights to a broader audience seems more difficult. Stakeholders who have not been part of the discussion missed the discussion and thereby the relevance of some facts, models, and their relationships. The step to politicians is especially challenging. Politicians have a rather different perspective. Could this be the reason that Stave and Hopper [44] position conceptual modeling so “low” in their taxonomy?

RQ2. How can such understanding help in reasoning about the solutions and, in that way, help in decision-making and preparing governance?

Several of the described events show that both conceptual models and the roadmap provide a reasoning framework for topics like local heat storage and positioning of solar farms. However, there is still a clear gap between understanding options for solutions and translating these into policy and legislation. There is a cultural and language mismatch between engineers and civil servants and politicians.

Fundamental to the decision-makers’ role, and at the core of politicians, is that they cope with emotions and perceptions. As Westen [45] states, “*In politics, when reason and emotion collide, emotion invariably wins.*” Thaler and Sunstein [46] describe how people make choices, indicating how important emotions are in decision-making. Lakoff elaborates on this in [47]. It is clear that just making technocratic conceptual models and roadmaps will not bridge the gap between experts and decision-makers.

RQ3. What is a manageable set of conceptual models to achieve understanding, reasoning, communicating, and decision-making?

A continuous challenge is to help stakeholders by offering them relevant information and sufficient context for a good discussion. The original roadmap workshop resulted in over 100 “issues.” So many issues overwhelm humans. Experienced systems architects use about 10 views to capture an architecture [48]. Borches [49] proposes A3 Architecture Overviews (A3AO). A3 refers here to the standard A3 paper size of 297 × 420 mm. In this research, inspired by the A3AOs, we combined a limited set of conceptual models on a single A3 to make the information digestible for the stakeholders.

These A3s worked well in the workshops about the roadmaps. Some of the stakeholders still feel overwhelmed by these A3s. However, in these workshops, they felt involved, engaged, and informed. However, we see that the problem identified in RQ2, e.g., the gap between experts and decision-makers, has its equivalence for information that stakeholders can share. Just condensing information in roadmaps and conceptual models is insufficient to bridge the gap between these parties.

Our experiences also make clear that introducing these methods is challenging, in itself, due to, among others, a lack of systems engineering competence, while many stakeholders prefer to stay in their local scope. We see this challenge in the limited scope of industrial application of systems engineering. Increasing the scope to a transition scope makes this



competence challenge significantly larger. Further research may help to find ways to introduce such competence.

## 6. Conclusions

The combination of conceptual modeling and roadmapping facilitates discussions between heterogeneous stakeholders on complex transition problems, such as the energy transition, at the local scale. However, there is a significant gap in the way of thinking and communicating between experts and decision-makers. Conceptual models and roadmapping may contribute to the societal challenge of the energy transition. However, humanity needs more means to bridge the transdisciplinary fields and the heterogeneous stakeholders.

Gerrit Muller worked from 1980 until 1999 in the industry at Philips Healthcare and ASML. Since 1999, he has worked in research at Philips Research, the Embedded Systems Institute, and TNO in Eindhoven. He received his doctorate in 2004. In January 2008, he became a full professor of systems engineering at University of South-Eastern Norway in Kongsberg (USN), Norway. He continues to work at TNO in a part-time position. Since 2020, he is INCOSE Fellow and Excellent Educator at USN.

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