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Decision making on regional energy transition
Models, tools and approaches

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The objective of this report is to identify tools, models and approaches that are relevant for decision making on regional energy transition. This report aims to provide an overview of approaches used in science and professional practice. Some of these approaches have been applied in the ESTRAC Regional Energy Transition project. This report is a starting point for the creation of a toolbox for the regional energy transition, which is one of the main deliverables of the project. The toolbox will enable stakeholders to find the right tools for individual regional energy transition cases.

This report is a deliverable of the ESTRAC "Case Studies Regional Energy Transition" project, commissioned and funded by the research institute Energy Systems Transition Centre (ESTRAC). ESTRAC is a joint initiative of knowledge and research institutes in the Netherlands – including TNO, ECN (since April 2018 part of TNO), University of Groningen, Hanze University of Applied Science, the New Energy Coalition (NEC) and, more recently, PBL – as well as associated partners including Gasunie, Gasterra, EBN and NAM. In addition to funding from the ESTRAC partners, the Case Studies Regional Energy Transition project has benefitted from funding by the Green Deal program of the Dutch government.

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1 Introduction

1.1 Overview, aims and objectives

Since the industrial revolution we have relied heavily on fossil fuels as feedstock and energy source. A major drawback in using fossil fuels is the emission of anthropogenic greenhouse gases. Deep reductions in these greenhouse gas emissions are needed if climate change is to be limited to 1.5-2°C above pre-industrial levels. These reductions will require a drastic transformation of the energy system as indicated by scenario studies which have evaluated possible roadmaps for this transformation. [1,2]

There is no straightforward solution to make a transition from a fossil-driven energy system to one based on renewables. There are many technological options to consider and which options work best depends to a great extent on local and regional circumstances. Therefore, it is increasingly recognized that the energy transition will take place at the local and regional level. This is where major decisions will have to be made.

Good information is crucial to allow decision makers to make well-informed decisions and to map possible future pathways. To help decision makers in deciding which mitigation options they want to implement, a myriad of tools, models and approaches have been developed. The focus of these tools, models and approaches varies considerably, e.g. some are determining societal support for specific mitigation options or for sustainability in general; some explore new business cases, assess the effect of technological improvements of specific processes; and others develop mitigation roadmaps. Stakeholders such as local governments and authorities, small, medium and large businesses, and consumers have different needs for information to enables them to develop strategies or make investment decisions.

The objective of this report is to provide an overview of tools, models and approaches used in science and professional practice. Some of these have been applied in case studies in the ESTRAC Regional Energy Transition project. This report is a starting point for the creation of a toolbox for the regional energy transition, which is one of the main deliverables of the project. The toolbox will enable stakeholders to find the right tools for individual regional energy transition cases.

Reading guide

This report provides an overview of existing tools, models, approaches and methodologies that are used for decision making on regional energy transition.

The first chapter introduces some key concepts (regional energy transition; decision making processes) and explains how they will be used in this document. This chapter sheds some light on definitions of tools, models and approaches. It also explains the methodology used in compiling this document. The second chapter describes currently available tools, models and approaches. This inventory is not aimed to be

[1] European Commission. *Energy Roadmap 2050*, EC, Brussel, December 2011.
[2] IEA. *Energy and Climate Change*, IEA, France, 2015.

exhaustive but rather to present examples, mainly focusing on the Netherlands. Finally, the last chapter of this report contains a brief discussion of the inventory.

1.2 Definitions and approaches used

This section deals with some of the definitions and approaches used in this document.

1.2.1 Regional energy transition

Regional energy transition is defined here as a process to achieve a certain outcome (deep greenhouse gas emission reduction) on a regional level. Although there are many interpretations of what constitutes a region (functional, administrative etc.) and how people relate to them, in the context of this study, a region is defined as a coherent geographical area, below the scale of the nation state, varying from a district to an area with several municipalities or cities. Provinces and distinct areas within provinces may also be ‘treated’ as a region, depending on the context. Regions may overlap or cross administrative (e.g. provincial) boundaries.[3] The regional energy system does not only have geographical boundaries, but also boundaries of its technical or economic system. The exchanges of the system over the boundaries have to be clearly defined.

Any regional energy system is linked to other spatial levels, such as to the national or country level, and internationally, as regional systems are also connected to other parts of Europe. On a lower spatial scale, regions are linked to local level areas, such as municipalities, villages, cities, and neighbourhoods. Figure 1 shows how a regional energy transition involves different geographical levels.

Regional energy transition then is a further specification of the area-based approach to the energy transition. It refers to the transition towards renewables in a confined geographical space (‘the region’), taking into account issues within that region such as spatial planning, choices concerning what to focus on in the transition (buildings, infrastructure, renewable sources), interaction with other domains, business cases, real and perceived barriers, social acceptance and technology innovation.

[3] In the energy debate, very often region and local are used as synonyms. Strictly speaking, the local or a locality is a lower spatial level than the regional level, often associated with a village or municipality. Local may also refer to neighbourhoods within urban areas. In this document we will stay as close to the strict/narrow interpretation of regional and local as possible.

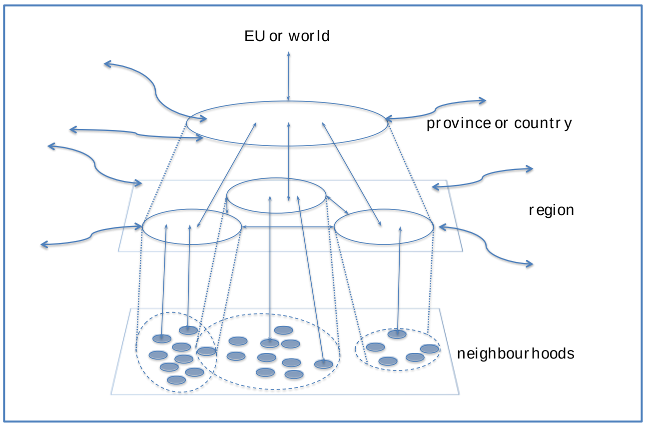

Figure 1 A regional energy transition involves different geographic levels

1.2.2 *Decision making*

Energy transition is a complex process that affects many aspects in society. Decision makers are in need for insights into the implications of interventions and for systematic comparisons of alternative options. A wide range of tools, models and methodologies is available to support decision-making. One commonly used framework or model is the policy or decision cycle. An example is the framework proposed by Carpenter et al.(2009) (see Figure 2).[4] In a general sense, this framework (and most of the other frameworks on the policy decision cycle) doesn't consider decision-making as a one-stop process (going through only one cycle), but rather as an iterative process in which one details and improves the outcome by continuously going through a next cycle.

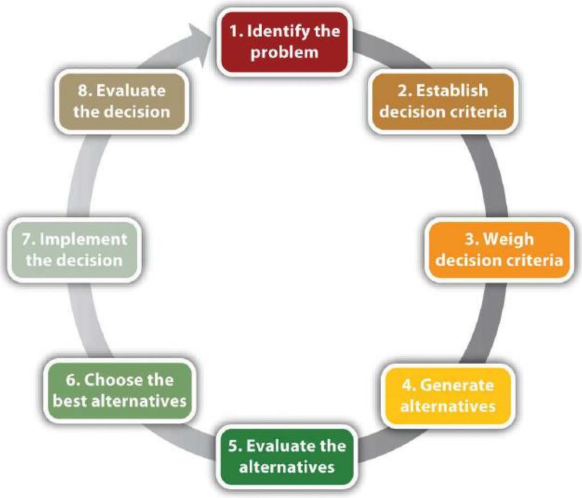

Figure 2. Rational decision steps by Carpenter et al. (2009)

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4 Mason A. Carpenter, Talya Bauer, Berrin Erdogan, *Principles of management*, Flat World Knowledge, 2009.

It is assumed here that different tools are used at different stages in the decision-making process. Some tools are very helpful in analyzing the problem in early stages of the process but are not suitable for assessing alternatives or for making final plans; other tools do the precise opposite.

1.2.3 Energy models, tools and approaches

Energy models, tools and approaches help decision makers to decide which, if any, sustainability options should be implemented. Some definitions and background information are provided here to bring some clarification in the use of the terms 'tools', 'models' and 'approaches' in this document.

Energy models
Energy models have a long history, and there are many reviews available that map the state of the art in energy system modelling. For example, Lopion et al. (2018) provides such a comprehensive overview and analysis of existing energy models[5]. Generally speaking, the aim of energy models is to give insight in how the energy system might change. Usually, energy models are based on a set of computer-generated calculations of (parts of) the energy system. Energy system models help decision makers to analyse energy systems systematically and to develop scenarios.

Tools
In the context of energy systems, the use of "tools" may lead to some confusion, as it often seems to be used randomly and synonymously to energy "model"- but it is not the same. In an easy definition a tool is a means that is used to reach a certain end. As such all energy models are tools that help to understand energy systems, but there are more tools available than energy models that also have this function.

Approaches
The term "approach" refers to the way of dealing with a particular problem or situation, in this case the energy transition. In this context, approach is a more general term or broad description used to include (a set of) measures or instruments used for a better understanding of and support for the energy transition. Energy models and tools may be considered dedicated approaches, but there are also other approaches that are used, often in a structured way, to address the issue at stake. It is also used as a synonym for methodology: a set or system of methods, principles and rules to address a particular issue – in this case the energy system. The use of the term approach is in particular relevant when considering the inclusion of stakeholders, which usually requires a structured set of actions.

In this document we intend to stick to the definitions provide here as much as possible. However, for pragmatic reasons we sometimes only use the terms tools when we refer to the entire spectrum of tools, models and approaches.

1.2.4 Methodology used for this report

This report focuses on tools that assist decision making for the energy transition on regional level. In terms of methods used, this report is based on a broad inventory.

[5] Peter Lopion, Peter Markewitz, Martin Robinius, Detlef Stolten, A review of current challenges and trends in energy systems modeling, Renewable and Sustainable Energy Reviews, Volume 96, 2018, Pages 156-166, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2018.07.045.

The inventory started with a broad analysis of recent (scientific) review articles and an internet search. In addition, other existing compilations were used. Finally, known models, tools and approaches as they were used and/or known by the knowledge partners of this project (Hanzehogeschool Groningen, University of Groningen, and TNO) have been added to the inventory. The inventory is not exhaustive, but rather presents examples. It serves as a starting point for the creation of a toolbox for the regional energy transition, which will enable stakeholders to find the right tools for individual regional energy transition cases.

The results of the inventory of tools is presented in Chapter 2. This broad inventory also includes tools that are not designed for the regional level per se but that are important to consider given links between the different spatial scales. We have selected a number of examples to illustrate the use of these tools. More detailed factsheets are available in the appendix.

2 Overview of tools, models and approaches

2.1 Introduction

There is a wide range of tools, models, approaches and methodologies available that can be used to support decision making on regional energy transition. There is an extensive body of review and overview articles and materials available. [6] This chapter aims to provide an overview of tools, models and approaches that are relevant within the context of ESTRAC.

A first question to ask is how to categorize or characterize the different models, tools and approaches. There is great diversity in the possible characterisations. For example, characterization may be based on the model type, the purpose of the model, the modelling paradigm, the underlying methodology, the resolution technique, geographical coverage, sectoral coverage, time horizon, data type, endogenization degree, and addressed side.[7]

Energy models often lack a social component and as such, they often exclude aspects such as human behaviour and socio-political or non-financial barriers to deployment of technologies. We specifically do want to include social aspect and participatory approaches in our inventory. For the purpose of this study, for the characterization or classification of the analysed models in this report we have chosen a pragmatic take as is presented below.

- General energy system models
- Dedicated models
- Social models & stakeholder approaches
- Models and tools for the built environment
- Integrated approaches.

It should be noted that each tool has its own focus and thus its own strengths and weaknesses, and some of the tools overlap. This chapter presents examples of models of the different types. A number of examples are described in more detail; the selection of these examples is based on experience of one of the knowledge institutes with this particular tool, model or approach. Table 1 gives an overview of the factsheets that are included in the appendix.

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[6] For example: Connolly D., Lund H., Mathiesen B.V., Leahy M., A review of computer tools for analysing the integration of renewable energy into various energy systems. Applied Energy 2010;87(4):1059-1082.; Peter Lopion, Peter Markewitz, Martin Robinius, Detlef Stolten, A review of current challenges and trends in energy systems modeling, Renewable and Sustainable Energy Reviews, Volume 96, 2018, Pages 156-166, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2018.07.045.

[7] For an analysis of categorization approaches see Naimeh Neshat, Mohammed Reza Amin-Naseri and Farzaneh Danesh. Energy models: Methods and characteristics. J. energy South. Afr. [online]. 2014, vol.25, n.4, pp.101-111. ISSN 2413-3051.

Table 1 Overview of factsheets on tools, models and approaches

Factsheet	Tool, model or approach	Type
A.1	BE+ Energy Potential Scan for Business Parks	Dedicated models
A.2	Built Environment Energy Neutral; Travel Guide for Transforming Local Regions	Integrated approaches
A.3	Energy System Description Language (ESDL)	General Energy System Models
A.4	Human Centered Design Approach (HCD)	Social Models & Stakeholder Approaches
A.5	Information Choice Questionnaire (ICQ)	Social Models & Stakeholder Approaches
A.6	Intervention Framework	Social Models & Stakeholder Approaches
A.7	MAFMETIS	Social Models & Stakeholder Approaches
A.8	National Energy Outlook Modelling System (NEOMS)	General Energy System Models
A.9	Option Portfolio for Emissions Reduction Assessment (OPERA)	General Energy System Models
A.10	Orchestrating Energy Transitions (Orchestration Innovation Model)	Social Models & Stakeholder Approaches
A.11	Process Energy Neutral Business Parks BE+	Dedicated models
A.12	Quick Guide Energy Project on Business Parks	Dedicated models
A.13	Quick Guide The Sustainable Home Owner Association	Dedicated models
A.14	Routeplanner Energieneutraal	General Energy System Models
A.15	Social Site Characterisation (SSC)	Social Models & Stakeholder Approaches
A.16	Stakeholder Engagement for Energy (SEE)	Social Models & Stakeholder Approaches
A.17	Study Energy Islands	Dedicated models
A.18	Target Energy System (TES) Methodology	Social Models & Stakeholder Approaches
A.19	Urban Learning Cycle	Integrated approaches
A.20	Value-based Experience Framework	Social Models & Stakeholder Approaches

2.2 General Energy System Models

Energy systems models allow the analysis of the energy supply and demand. These models are used as a tool to quantify scenarios and to formalize scattered knowledge about complex interactions.[8] Although energy system models are often designed for

[8] Pfenninger S., Hawkes A., Keirstead J., *Energy systems modeling for twenty-first century energy challenges*, Renewable and Sustainable Energy Reviews 33 (2014) 74-86.

the national or international level, they can be used on lower spatial levels as well.

Many energy system models use optimization or simulation techniques.

- **Optimisation models** are used to determine a preferred mix of technologies, given certain constraints. These models are typically data intensive and complex.[9] An example of such a model is the OPERA model[10], which is used to develop cost-optimal long-term climate strategies for the Netherlands;
- **Simulation models** attempt to reproduce the operation of an energy system by simulating the behaviour of energy producers and consumers in response to prices and other signals. For example, the *National Energy Outlook Modelling System* simulates energy use and emissions of the Dutch energy system and is used for energy outlooks and policy evaluations.[11] Simulation models are often complex and opaque, due to the requirement of assumptions about behavioural factors (Hall and Buckley, 2016).

Bottom-up (cost) engineering can support decision making at the regional and local level. Other common modelling approaches are based on neural networks, agent-based modelling, complexity science and fuzzy theory (Hall and Buckley, 2016);

Example: Energy Transition Model (ETM)[12]

The Energy Transition Model (ETM) is an open source model that has been developed by Quintel Intelligence. It is freely available on a website. The model describes the complete energy system of a country. For each sector, such as households or industry, users can investigate the future energy system by making choices about supply and demand of various types of energy. The model then provides indicators for the sustainability, reliability and affordability of the energy system for all stakeholders.

The model is used as a supporting tool for discussions on energy in the public sector, by corporations, NGO's and educators. The model does not attempt to find an optimal solution, but allows the user to see what impact choices have on the outcomes of the model. The model contains technical and financial parameters for hundreds of technologies.

Example: PICO[13]

PICO is a free web-based platform or application that allows users to analyse options for sustainable energy in the built environment. PICO uses different spatial, social, economic and financial models and data, including for instance the VESTA model. PICO aims to provide users with information that allows them to explore different options and scenarios such as for instance energy saving measures or the consequences of PV installation. The geographical or spatial component of PICO is highly developed: the platform uses maps to visualize different options. The maps can be created on different spatial levels from individual building to a region. PICO supports different stakeholders such as municipalities, project developers and

[9] Hall L.M.H., Buckley A.R., *A review of energy systems models in the UK: Prevalent usage and categorisation*, Applied Energy 169 (2016) 607-628.

[10] See Factsheet A.9.

[11] See Factsheet A.8.

[12] www.energytransitionmodel.com; Energietransitie Rekenmodellen: Energietransitiemodel, https://www.netbeheernederland.nl/.

[13] Energietransitie Rekenmodellen: Pico, https://www.netbeheernederland.nl/; https://www.geodan.nl/nl/producten-en-diensten/decentrale-overheid/pico/.

housing associations in their decision-making process in relation to the energy transition. It allows users to explore and access different scenarios in a multi-stakeholder setting. The platform is partly free and web-based communities and individual house owners also have easy access to the information. PICO is also available as a paid service to allow users to set up their own environment. In this standard energy data and models can be combined with specific data. Within this paid service, users have an information facility that automatically develops with the project or program. This way, accumulated knowledge is safeguarded and remains available for the next phase of, for example, an area development process.

2.3 Dedicated Models

Some models are dedicated towards specific parts of the energy system. For example, some of the models deal with specific technological options such as the use of hydrogen. These models are typically developed to gain insight into what sustainability options are available, what their effect is and what the cost might be. A number of other approaches listed here have been developed for specific type of areas such as business parks.

Example: Energy System Description Language (ESDL) [14]
The Energy System Description Language (ESDL) is a programming language to describe the energy system of a certain region with all its relevant components and additional information of the region that relate to energy system challenges. It supports all possible commodities (electricity, gas, heat, …). All energy system components (like heat pumps, windturbines, heat networks) can be derived from these capabilities. The language also uses the concept of hierarchy and aggregation. A region can for example be modelled at house level, street level, neighbourhood level or city level in a similar way. Capabilities can be aggregated from a lower to a higher level to make it easy to do all kind of calculations and comparisons. The language also allows to define possible measures that are optionally implemented, which is very well suited to support energy transition modelling tools. The language can be used to give a uniform input to different energy transition modelling tools in order to make their output more comparable. Next to these core energy related concepts, the language supports modelling regional information about things like number of inhabitants, average income, building information, mobility needs, and so on. The language allows users to model any energy system on every scale, varying from a very detailed level to a very high (abstract) level.

Example: BE+ Energy Potential Scan for Business Parks[15]
The Energy Potential Scan for Business Parks (EPS), part of the BE+ approach, calculates the business case for sustainable energy measures on business parks. It uses parameters for energy measures and geographical data (open data or commercially available). Measures include: isolation of facade, roof and glass surfaces, heat recovery, LED, PV and heat pumps. Results are presented for individual companies and for the business park as a whole.

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[14] See Factsheet A.3.
[15] See Factsheet A.1.

The EPS has been developed in practice and successfully applied for several business parks in the Netherlands, also as a commercial product. The input parameters have been defined together with WM3 Energy consultants. The EPS gives a first overview of the opportunities for sustainable energy measures on business parks. It requires no information from the companies themselves and is thus a quick and cost-effective scan. The results of EPS can later be refined with on-site acquired information on e.g. energy use and taken measures. The results are not always accurate for each company, as companies can only be limited represented by national data sets and parameters. This should clearly be communicated when presenting the results

2.4 Social Models & Stakeholder Approaches

Increasingly it is realised that the energy transition presents more than just technological challenges. The inclusion of social aspects into models and the inclusion of stakeholders into energy-related decision-making processes have become widespread practice. A distinction can be made between:

1. models that include social data and stakeholder preferences in the modelling of energy systems, and
2. approaches that include stakeholders into decision making processes.

In particular in the built environment the inclusion of social aspects and stakeholders is – given the sector at hand - self-evident. The section that focusses on built environment (Section 2.5) will therefore address additional social models and stakeholder approaches.

Example: Target Energy System (TES) Methodology[16]

The Target Energy System (TES) methodology developed by TNO helps to assess possible future solutions for the energy transition. It comprises of both a process/workflow to define the ambitions with the involved stakeholders and a calculation model to assess the impact of all required choices. The methodology requires some information about the region: demography; current (yearly) energy usage (electricity, gas and heat) of different sectors; the building stock; mobility needs, and the specifics of the surrounding region and possible sources of energy. It results in several options (scenarios) that fit the ambitions of the stakeholders. Scenarios can be compared using approximately 15 key performance indicators covering both environmental aspects, financial aspects and social aspects. The methodology has been applied in practice in two commercial projects on neighbourhood and regional scale. One of the applications was in a region with several small cities and villages, with a large agricultural area in between. Several scenarios for the target energy system were assessed.

The TES methodology assumes certain trends in relevant parameters for the model (number of inhabitants, energy usage, mobility needs) and jointly defined scenarios based on regional possibilities (e.g., taking into account biogas potential based on agricultural data and yearly sewage information, the potential role of cooling houses in the energy system, the option to become a mobility hub for a neighbouring large city, combining electric vehicle charging possibilities with high speed public transport).

[16] See Factsheet A.18.

Example: Value-based Experience Framework[17]

Initiatives to promote energy transition can benefit from a holistic approach that acknowledges a system's overall capacity, willingness and affordances towards change. Based on scientific literature, TNO developed a design-oriented quadruple helix approach to energy transition. This value-based framework addresses willingness and ability to change. The approach takes into account the value system of the stakeholders and establishes common ground and a shared vision towards the outcomes. The participatory design process increases trust and cohesion among the stakeholders. Trust between stakeholders is key to successful transitions.

The approach has been applied in different projects. Preliminary results from using this approach indicate the prevalence of different conflicting values, interests and concerns between stakeholders. Addressing these conflicts at the right time and through collaboration is considered fruitful. This results in a more successful transition processes, within a shorter time period, better relationships between stakeholders and more stakeholder satisfaction. The experience with this approach in the energy domain is still limited.[18]

Example: MAFMETIS[19]

At any scale, sustainable energy initiatives and projects have to deal with multiple stakeholders and multiple interests. Although, in theory, very often the required means (both financial and non-financial), knowledge and expertise are available, in practice they are divided among different actors. Moreover, the actors that bear the costs are not always the same actors that benefit from a sustainable energy investment. It demands a great deal of coordination and cooperation to turn inspiring ideas into successful projects.

The MAFMETIS tool is a process instrument that actors can use to facilitate a transparent dialogue and tailor financial instruments to overcome potential boundaries for collaborative investments. The method is built up from six building blocks or themes that are crucial in the process from inspiring idea to successful sustainable energy investments. These building blocks consist of several questions that need to be answered or at least thought through by the involved actors of a specific project. The questions are presented on little cards, that allow for having an open dialogue in a kind of game setting. Actors can prioritize the questions, put questions aside, structure or group questions and themes etc.

Going through the methodology requires several workshops with different private and public stakeholders. The MAFMETIS methodology is applied in different cities at this moment and is well embedded within scientific literature on game theory, multi stakeholder processes, integrated planning and transdisciplinary knowledge development. The MAFMETIS tool is a holistic and systemic way of looking at investment processes. It might be applied to every sector, but always by taking other sectors into account. It is very useful to facilitate processes of collaborative investments in regions.

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17 See Factsheet A.20.

18 Kort, J., Koning, N. de, and Gullström Hughes, C., Creating successful transitions in energy, By respecting stakeholder values and securing trust and cohesion, Energy-Open 2017 https://energy-open.nl/local/abstracts/024_kort.pdf.

19 See Factsheet A.7.

2.5 Models and Tools for the Built Environment

Many of the general tools, models and approaches introduced may be used in the built environment. However, a number of them are especially developed and or relevant in the context of built environment. What most of these models and tools have in common is their spatial basis. Some are aimed towards a particular technical option such as PV or wind. A number of tools are clearly based on involving stakeholders because, as was mentioned before, a large part of what constitutes the built environment are dwellings of people. Many of the built environment tools and approaches have a strong geographical component. The broad spectrum of tools for the built environment covers different spatial levels (house, street, neighbourhood, city etc.). Finally, as measures in the built environment directly influence people's living environment, some of the built environment related tools and approaches are specifically aimed to visualise energy measures (e.g. windmills, solar PV) in the landscape.

Example: VESTA MAIS[20,21]

VESTA MAIS is a commonly used spatial energy model of the built environment including housing, offices, shops and hospitals. VESTA MAIS aims to explore options to reduce CO_2 emissions through techno-economic modelling of options for energy saving, renewable energy and heat networks. VESTA MAIS is a simulation and/or an optimisation model that is able to calculate measures or options on the level of buildings and larger-scale areas.

The VESTA MAIS model was developed by PBL and is used by national and local policy makers, in particular in relation to the 'heat market'. The model calculates costs and benefits for energy supply in the built environment for different actors/stakeholders: producers, transporters, distributors, suppliers, investors, owners and users of buildings. The model takes into account depreciation and removal of the gas network and investments in the electricity grid. The model also takes into account socioeconomic characteristics of households and businesses.

The model is open source. Spatial data is derived from the BAG (Basisregistratie Adressen en Gebouwen). Energy data is derived from sources of RVO, TNO and CE Delft. The output are maps, graphics and tables on the energy use of different actors in the built environment.

Example: Energie Transitie Atlas (Over Morgen)[22]

The Energie Transitie Atlas (Energy Transition Atlas) is a tool that was developed by Over Morgen. The Atlas helps regional governments, energy companies and housing associations to implement energy transition policies. The atlas covers heating, sustainable production and mobility. Technological options and the landscape are described on different spatial levels.

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[20] Ruud van den Wijngaart, Steven van Polen en Bas van Bemmel (2017), Het Vesta MAIS ruimtelijk energiemodel voor de gebouwde omgeving, Den Haag: PBL.

[21] Energietransitie Rekenmodellen: VESTA, https://www.netbeheernederland.nl/.

[22] Energietransitie Rekenmodellen, Energie Transitie Atlas, https://www.netbeheernederland.nl.

The tool is orientated towards involving different stakeholders in the transition process. The Atlas is able to map out the current situation, the ambition and the quick wins for the short term. It starts from an area-based approach and gives insight in heat flows and local sustainable energy production in a neighbourhood or building, presenting results on an online map. The local landscape determines the potential output of renewable production and compares this with local demand.

The Energy Transition Atlas is based on open source data and uses BAG (Basisregistratie Adressen en Gebouwen), TOP10NL and energy use data. The user interface is interactive and online, using a GIS platform. ETA has to be prepared for areas by experts. It is a supporting tool, used in consultancy and advisory work.
Example: Smart Energy City[23]

Smart Energy City is an integrated approach that combines a social and societal approach with technological and economical innovations. Smart Energy Cities is developed by a public-private partnership of the Ministries of Economic Affairs, the Ministry of the Interior and Kingdom Relations, Netbeheer Nederland, TKI Urban Energy and TKI ClickNL. The approach was developed to assist municipalities and neighbourhoods in making plans for the energy transition, in particular in finding alternatives for natural gas. The approach was developed and tested in 16 neighbourhoods in the Netherlands where professionals were teamed with municipalities, residents and housing associations.

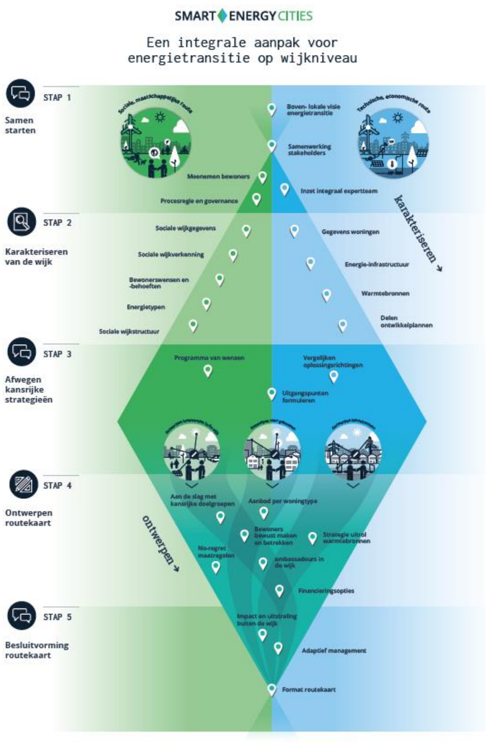

Figure 3 Smart Energy City

The approach that was developed is (visually) characterised by two tracks: a societal track in green and a technical-financial track in blue (see Figure 3). Both tracks are

[23] https://www.smartenergycities.nl/over-smart-energy-cities/

simultaneously developed to result in a roadmap for the energy transition. The approach takes participants through two phases: a first phase to characterise both the societal (e.g. demographics) and technical components (e.g. current energy use) and a second phase to develop and design new plans. The roadmap generally consists of specific actions for certain types of houses; steps to be taken to develop a new energy system; a communication strategy and an investment program for the first 1 to 2 years.

This approach is strongly focused on process, governance and decision-making including the inclusion of stakeholders. Smart Energy City also facilitates adaptive management: for example, a neighbourhood can start with no regret measures for a small number of houses and decide later about whether or not new heating systems should be adopted. The end result is an integrated and adaptive roadmap for a long-term period.

Example: Charrettes[24]
Charrettes are collaborative sessions in which a group of designers drafts a solution to a design problem. Typically, it is a focused, multiday session that uses a collaborative approach to create realistic and achievable designs. Although originating from the field of design, charrettes take place in many disciplines. Charrettes can help to create trust and build consensus by allowing participants to be part of the decision-making process.

In the field of energy, charrettes have been used and developed in the Grounds for Change project as part of an area-based approach towards the energy transition.[25] These are interactive, interdisciplinary design sessions in which experts and professionals work together with the inhabitants of a certain area on the energy transition. In this way the expertise of experts and professionals is matched with local and regional knowledge and through a process of co-creation, resulting in a joint sense of ownership, and a higher public support in the implementation phase.[26]

Over the past few years the Hanze University of Applied Sciences in Groningen has experimented with charrettes in different areas. One example is the isle of Ameland where in 2017-2018 a series of charrettes were organised.

Example: We Energy Game[27]
The We Energy Game provides insights about the provision of affordable energy from renewable sources for an entire town or city. The game is based on a model that relates scores to different components of the energy system. These scores are based on realistic impacts of each variable, referring to the (amount of) energy, emissions and impact. The challenge of the game is to find the optimal balance. The We Energy Game was developed to provide energy cooperatives and stakeholders with practical insight into the possibilities to actually achieve energy neutrality. During the game participants negotiate about the use of renewable energy sources in order

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[24] Gail Lindsey, Joel Ann Todd, Sheila J. Hayter, A Handbook for Planning and Conducting Charrettes for High-Performance Projects, NREL, 2003.
[25] Noorman, K.J.; de Roo, G. *Energielandschappen: De 3de generatie. Over regionale kansen op het raakvlak van energie en ruimte*; Provincie Drenthe: Koekange, The Netherlands, 2011.
[26] Klaas Jan Noorman, Over energietransitie en zo veel meer, Lectorale rede Hanzehogeschool Groningen, 2018.
[27] We-Energy Game – Bordspel, https://www.we-energy.eu/

to make a town or city energy neutral. In addition, considerations and interests in several areas are included (production, people, planet, profit, space, and regulation).

By playing the game, participants become aware that there is not a single solution and that sustainability is not just a technical issue, but a social one as well. For example, even though there is great support for solar panels, the sun doesn't always shine. This means that other resources are needed. Wind provides a lot of energy, but also encounters local resistance. Biomass could be a good solution, but its environmental footprint is greater. Thus, each source has its advantages and disadvantages. The We Energy Game is used particularly to create awareness.

2.6 Integrated approaches

Many of the tools presented before focus on technical aspects of the energy system (in a particular region): simply put, many of the tools are aimed to calculate what the best technological or economic solution in a certain area would be. Although this may feed into the decision-making processes in a particular region, exceptions notwithstanding, it is very often not part of the same process or approach. However, over the last few years there have been a number of experiments in professional practice that have applied a more integrated approach. This is defined here as an approach used to support the organisation of a decision-making process in a certain municipality or region in relation to the energy transition an overall or integrated way.

Example: Gebieden Energie Neutraal (GEN)[28]

Gebieden Energie Neutraal (energy neutral areas) was a project that was ran from 2010 to 2014 by a number of companies and knowledge institutes, including TNO. The project focused on developing tools and guidance to make the built environment energy neutral. There was also a practical component: implementation of the tools in a number of pilot cases in a number of city districts.[29] The main added value of this project was that these cases were closely evaluated. For this evaluation the learning history method was used.

The main lessons learned were:

- A common and shared end goal is the most important factor to produce lasting results and collaboration. Only such a common objective can lead to moving together in the desired direction. In the beginning, starting to move is more important than achieving energy neutrality.
- The energy transition is a relatively new and innovative development. This means that its character is not strictly goal oriented but rather goal searching: the goals develop alongside the process (they are not fixed from the beginning). This requires flexibility of everyone involved; it requires an adaptive approach and it requires a permanent reflection on what is happening. This also means that the persons and organizations involved vary. It requires using dynamic ways to enter into agreement instead of static ways.
- The transition has to deal with a lot of dilemmas (co-creation of residents or top-down planning; hard or soft results; city as the local champion or as the facilitator). One has to find a way to deal with these dilemmas together (and take time for collaborative discussions).
- It is crucial to collaborate with local companies, especially with local sustainable energy suppliers.

[28] See Factsheet A.2.

[29] These cases were: Kerschoten, Apeldoorn, Rubroek, Rotterdam, Valkenburg and Katwijk.

Together the lessons and experiences of GEN led to the final product: 'Travel Guide for Transforming Local Regions'. The 'travel guide' is a report in which local authorities can find guidance for their efforts to come to an effective and efficient approach for a local energy transition.

Example: Urban Learning Cycle[30]

The Urban Learning Cycle improves urban policy and decision making. It is a methodology to get in depth insight in the entire urban policy making cycle. Through this methodology policy makers become aware of the interlinkages between policy stages and different knowledge demand in each stage. Not only does the Urban Learning Cycle provide an answer to the challenge of closing the actual cycle, it also provides clues on how to deal with the main challenges of urban policy making: cross-domain integration, organizational integration, dealing with decision making contexts and developing local innovation ecosystems.

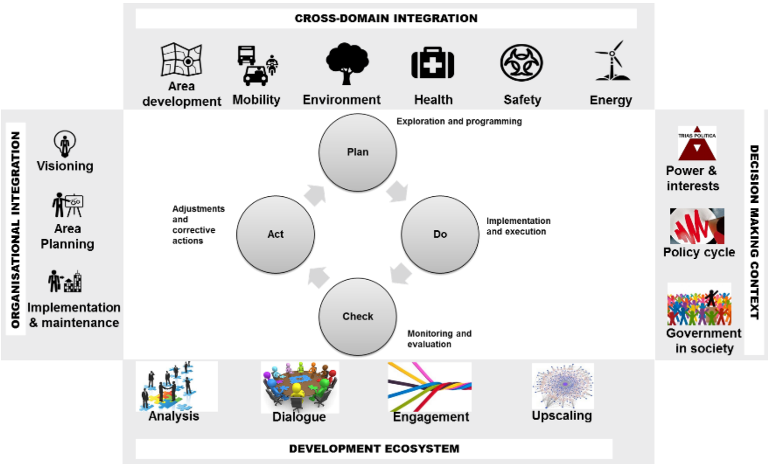

Figure 4 Urban Learning Cycle

Application of the methodology requires several workshops with different stakeholders within the public body. The Urban Learning Cycle methodology has been applied in different cities and is well embedded within scientific public administration literature. The Urban Learning Cycle is a holistic and systemic way of looking at policy development.

Example: Smart Sustainable Districts approach for the city of Utrecht

The Smart Sustainable Districts (SSD) program of Climate-KIC works closely with highly ambitious city districts across Europe to overcome barriers and identify solutions that meet their climate change ambitions. The focus of SSD is on integrating new technologies and approaches – like district heating, smart grids, demand management and resource sharing – that need support to be implemented in practice. At the district level it is possible to test this support through new models of financing and contracting, joint ventures, partnerships, community engagement or novel governance models. Districts provide the appropriate scale to implement integrated solutions that deliver measurable environmental, social and economic

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30 See Factsheet A.19.

benefits. These solutions provide exemplars that can also be replicated citywide or in other districts. In 2015, an SSD project started in the city of Utrecht, more exactly in the district Beurskwartier, a district in the centre of the city.[31] The two main stakeholders in the redevelopment of this district are the municipality of Utrecht and the Jaarbeurs B.V. (a company that exploits the large exhibition and meeting facilities in the district). The results of the approach were integrated into the formal spatial development plan of the city and were also incorporated into the new master plan of the Jaarbeurs.

[31] https://ssd-utrecht.nl/over-smart-sustainable-districts/het-ssd-project/?lang=nl

3 Discussion

The aim of this report is to provide an overview of tools, models and approaches that can help the decision-making process in regional energy transition. Some of these have been applied in case studies in the ESTRAC Regional Energy Transition project.

As this report shows, a wide variety of models, tools and approaches is available to help stakeholders to make well-informed decisions. As mentioned, there are many more energy tools, models and approaches available, as well as useful reviews and overviews. The information presented here is a selection based on what is most appropriate in the context of the ESTRAC project.

For the purpose of this study, we have chosen a pragmatic take for the classification of the analysed models in this report.

- Energy systems models allow the analysis of the energy supply and demand. These models are used as a tool to quantify scenarios and to formalize scattered knowledge about complex interactions.
- Dedicated models are dedicated towards specific parts of the energy system. These models are typically developed to gain insight into what sustainability options are available, what their effect is and what the cost might be.
- The inclusion of social aspects into models and the inclusion of stakeholders into energy-related decision-making processes have become widespread practice. A distinction can be made between models that include social data and stakeholder preferences in the modelling of energy systems, and approaches that include stakeholders into decision making processes.
- A number of the tools, models and approaches are especially developed and or relevant in the context of built environment. When considering the energy transition in the built environment, stakeholder approaches are intrinsically linked to the subject: as any transition in this domain affects and involves people, the inclusion of stakeholders becomes by definition (at least in our society) part of the process.
- Integrated approaches are used as well. These are defined here as approaches that are used to support the organisation of a decision-making process in a certain municipality or region in relation to the energy transition in an overall or integrated way. There are many overall approaches available that have their roots in the concepts and approaches used in planning methods in general and (sustainable) urban planning in particular.

This report is a starting point to the creation of a toolbox for the regional energy transition, one of the main deliverables of the ESTRAC project. This toolbox will include a methodology that enables stakeholders to find the right tools for individual (regional energy transition) cases.

A Factsheets on tools, models and approaches

A.1 BE+ Energy Potential Scan for Business Parks

Name	BE+ Energy Potential Scan for Business Parks
Type	Dedicated Models
Developer	TNO
Short description	The BE+ Energy Potential Scan for Business Parks (EPS) calculates the business case for sustainable energy measures on business parks. It uses parameters for energy measures and geographical data (open data or commercially available). Measures include: isolation of facade, roof and glass surfaces, heat recovery, LED, PV and heat pumps. Results are presented for individual companies and for the business park as a whole. The EPS has been developed in practice and successfully applied for several business parks in the Netherlands, also as a commercial product. The input parameters have been defined together with WM3 Energy consultants.
Scale	Neighbourhoods (specifically business parks)
Timescale	Years
Applications	The EPS gives a first overview of the opportunities for sustainable energy measures on business parks. It requires no information from the companies themselves and is thus a quick and cost-effective scan. The results can later be refined with on-site acquired information on e.g. energy use and applied measures. The EPS is part of the 'Bedrijventerreinen Energiepositief' (BE+) approach.
Limitations	The results are not always accurate for each company, as companies can only be represented by national data sets and parameters. This should clearly be communicated when presenting the results.
Reference	- Energie potentieelscan[32] - Bedrijventerreinen Energiepositief[33]

[32] https://www.bepositief.nl/energie-potentieelscan/
[33] https://www.bepositief.nl/

A.2 Built Environment Energy Neutral; Travel Guide

Name	Built Environment Energy Neutral; Travel Guide for Transforming Local Regions (“Bestaande bouw energieneutraal: Reisgids voor een gebiedsgerichte aanpak”).
Type	Integrated Approaches
Developer	TNO, RoyalHaskoningDHV, ArtEnergy, Cofely (partners of the consortium Gebieden Energie Neutraal, GEN)
Short description	The travel guide supports everyone who wants to transform local regions. It describes the journey, helps you to get the right company during your journey, to plan your route and manage the obstacles during the journey. The travel guide refers to tools and publications that can be used during the journey. The guide has been used in practice and is based on desk research and on practical experiences (a.o. in Apeldoorn).
Scale	The guide can be applied at different levels, such as neighborhoods and cities.
Timescale	-
Applications	- Practical guide with many tips and references to tools and publications. - Development is based on real cases for newly built and existing areas (Apeldoorn and Katwijk). - Takes into account the governance and spatial process. - Mainly qualitative. - Well aligned trade-off between measures on district and building level. - Takes into account the lowest cost for households.
Limitations	-
Reference	René Idema and Nicole de Koning, *Bestaande bouw energieneutraal: Reisgids voor een gebiedsgerichte aanpak*, Gebieden Energie Neutraal, 2014.[34]

[34] https://www.tno.nl/media/1111/reisgids-gen-bestaande-bouw-energieneutraal.pdf

A.3 Energy System Description Language (ESDL)

Name	Energy System Description Language (ESDL)
Developer	TNO
Type	Dedicated Models
Short description	The Energy System Description Language (ESDL) is a language to describe the energy system of a certain region with all its relevant components and additional information of the region that relate to energy system challenges. ESDL supports all possible commodities (electricity, gas, heat, etc.). All energy system components (like heat pumps, wind mills, heat networks) can be described. The language also uses the concept of hierarchy and aggregation. A region can for example be modelled at house level, street level, neighbourhood level or city level in a similar way. Capabilities can be aggregated from a lower to a higher level to make it easy to do all kind of calculations and comparisons. The language also allows to define possible measures that are optionally implemented, which is very suited to support energy transition modelling tools. Next to these core energy related concepts the language supports modelling regional information such as the number of inhabitants, average income, building information and mobility needs.
Scale	The language supports any modelling scale (house, street, neighbourhood).
Timescale	The language supports the definition of energy profiles for consumption and production. It allows both to include average energy usage figures per system component and to refer to a detailed profile in a database.
Applications	- The language can be used to give a uniform input to different energy transition modelling tools in order to make their output more comparable. - The language allows to model any energy system on whatever scale, on a very detailed level or on a very high (abstract) level.
Limitations	If the language is used to model an energy system on a very detailed level, the required effort is large.
Reference	- Grip op de energietransitie met ESDL[35] - ESDL documentation[36]

[35] https://www.tno.nl/nl/aandachtsgebieden/informatie-communicatie-technologie/expertisegroepen/monitoring-control-services/grip-op-de-energietransitie-met-esdl/
[36] https://energytransition.gitbook.io/esdl/

A.4 Human Centered Design Approach

Name	Human Centered Design Approach (HCD)
Type	Social Models & Stakeholder Approaches
Developer	Several organisations amongst which Stanford University.
Short description	The Human Centered Design Approach has been defined in an ISO standard: "*Human-centered design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, usability knowledge, and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance*." ISO 9241-210:2010(E). The approach is used to develop a solution for a target group and requires information about their needs, drivers and perceptions. Solutions are found in co-creation with end-users. The end-user is a co-owner and is actually responsible for the development process. HCD is mainly used within companies to improve organisational processes and software, and within local communities to improve facilities. The approach is based on scientifically sound research methods and theory on public engagement. ECN applied this method in the H2020 project INDUCE, which has the goal to develop effective methods to let companies save energy.
Scale	Neighbourhood, district
Timescale	Continually throughout the lead time of a project.
Applications	Through intensive contact with end-users there is involvement and support from the start. The approach aligns well with 'Participatory Action Research', which currently is popular.
Limitations	The approach implies that the end-user can articulate what he or she wants with some help. The application is therefore limited to solutions that can be made sufficiently concrete. Very innovative solutions may not be selected.
Reference	Design Kit: The Human-Centered Design Toolkit[37]

[37] https://www.ideo.com/post/design-kit

A.5 Information Choice Questionnaire (ICQ)

Name	Information Choice Questionnaire (ICQ)
Type	Social Models & Stakeholder Approaches
Developer	Peter Neijens and Willem Saris, Universiteit van Amsterdam
Short description	The method provides insights into public preferences with regard to various alternative solutions after receiving objective, balanced and validated information. As input, it requires a (policy) problem, possible solutions, advantages and disadvantages of each solution, described in simple Dutch language. An ICQ requires broad expertise to compile the content and social-scientific expertise to do measurements and analyse the results. ICQ is a validated scientific measuring instrument. ECN has applied the methodology within the CATO and CATO2 projects.
Scale	Regional, provincial and national level
Timescale	The lead time is approximately one year. The preparations are time-consuming.
Applications	- The ICQ has a strong methodological advantage over surveys measuring uninformed opinions. The researchers found that informed opinions extracted with the ICQ were largely based on the information provided, were more consistent in time than uninformed opinions, and are thus better indicators of actual public opinion (De Best-Waldhober et al., 2009). - Another advantage of the ICQ is process-related: respondents highly appreciated the method and the information that was given. - Finally, an ICQ can be used as a tool for deliberative democracy, enabling every citizen to take part in solving a complex policy problem.
Limitations	- Application of the ICQ method is time-consuming and requires specific expertise. - An ICQ does not necessarily include all possible considerations that are relevant for the local population. Information, design and order effects may occur, despite precautionary measures. - The procedure is intensive for respondents.
Reference	- Neijens, P. (1987). The Choice Questionnaire. Design and Evaluation of an Instrument for Collecting Informed Opinions of a Population. Amsterdam, Free University Press. - De Best-Waldhober, M., Daamen, D., Faaij. A., 2009. Informed and uninformed public opinions on CO_2 capture and storage technologies in the Netherlands. International Journal of Greenhouse Gas Control 3(3): 322-332.

A.6 Intervention Framework

Name	Intervention Framework
Type	Social Models & Stakeholder Approaches
Developer	TNO
Short description	Transforming Local Regions requires that many target groups (e.g. home owners and SME's) change their behaviour (e.g., saving energy, investing in sustainable home improvements). In order to change behaviour the right interventions have to be defined, matching with the drivers/barriers of the target group. The Intervention Framework consists of four types of interventions (enabling strategies, antecedent strategies, removing barriers and consequence strategies). The framework helps to define the right interventions for the right target groups so that they successfully change their behaviour. The framework has been used in many projects and is based on scientific research.
Scale	Neighbourhood, district, city
Timescale	-
Applications	The framework helps in defining the right interventions for the right target groups so that they successfully change their behaviour (e.g., saving energy, investing in sustainable energy solutions).
Limitations	-
Reference	Roelien Attema, *Energy saving behaviour: What are we talking about and how can we change it? An Intervention Framework*, 2012.

A.7 MAFMETIS

Name	Multi Agent Financial Modelling in Energy efficiency Towards an Investment Strategy (MAFMETIS)
Type	Social Models & Stakeholder Approaches
Developer	TNO, Institute for Sustainability (UK)
Short description	At any scale, sustainable energy initiatives and projects have to deal with multiple stakeholders and multiple interests. Although, in theory, very often the required means (both financial and non-financial), knowledge and expertise are available, in practice they are divided among different actors. Moreover, the actors that bear the costs are not always the same actors that benefit from a sustainable energy investment. It demands a great deal of coordination and cooperation to turn inspiring ideas into successful projects. With the MAFMETIS tool actors can facilitate a transparent dialogue and tailor financial instruments to overcome potential boundaries for collaborative investments. The method is built up from six building blocks or themes that are crucial in the process from inspiring idea to successful sustainable energy investments. These building blocks consist of several questions that need to be answered/thought through by the involved actors of a specific project. The questions are presented on little cards, allowing open dialogue in a kind of game setting. Actors can prioritize, put aside, structure or group questions and themes. Applying the methodology requires several workshops with different private and public stakeholders. The MAFMETIS methodology is applied in different cities and is well-embedded within scientific literature on game theory, multi stakeholder processes, integrated planning and transdisciplinary knowledge development.
Scale	Project, neighbourhood
Timescale	- Several months are needed to conduct the workshops. - Investment projects typically last for many years.
Applications	- A transparent dialogue between project partners on the characteristics of the project and its particular collaborative investment needs. - Suitable and tailored financial/business model instruments that help to overcome problems in coordination and cooperation.
Limitations	- The tool provides a holistic and integrated view. It takes time and engagement of many relevant stakeholders to actually come to collaborative investments. - Tool needs to integrate qualitative approaches toward ‘trust’ and community building with quantitative and financial analyses.
Reference	MAFMETIS: Multi Agent Financial Modelling in Energy efficiency Towards an Investment Strategy[38]

[38] https://systemssolutions.org/projects-and-activities/mafmetis/

A.8 National Energy Outlook Modelling System (NEOMS)

Name	National Energy Outlook Modelling System (NEOMS)
Type	General Energy System Models
Developer	PBL and TNO
Short description	The National Energy Outlook Modelling System allows to calculate energy use and emissions for the Dutch energy system and for individual sectors. It is used for energy outlooks and policy evaluations. Each year, the modelling system is used for the Climate and Energy Outlook. The modelling system consists of energy models that exchange data and produce consistent and detailed results. Detailed results include energy demand, energy supply, emissions, technology uptake, investments, energy costs, energy prices and policy impacts.
Scale	National (The Netherlands)
Timescale	Years
Applications	- The national energy outlooks provide a well-defined reference scenario. - The modelling results give insights into developments in end-use sectors and the energy sector.
Limitations	- The modelling system is large and complex. Not all the couplings between models are used for the current reporting. - The system provides results at a national level which are not always detailed enough to analyse specific developments within sectors or regions.
Reference	- National Energy Outlook Modelling System[39] - Jeroen Peters and Cees Volkers, *Korte modelbeschrijving NEV-RS*, PBL, 2019.[40]

39 https://www.pbl.nl/modellen/kev-rekensysteem.
40 https://www.pbl.nl/sites/default/files/downloads/pbl-2019-korte-modelomschrijving-nev-rs_3870.pdf.

A.9 Option Portfolio for Emissions Reduction Assessment (OPERA)

Name	Option Portfolio for Emissions Reduction Assessment (OPERA)
Type	General Energy System Models
Developer	PBL and TNO
Short description	The OPERA model is a linear optimization model for the Dutch energy system that allows to assess technology portfolios for (deep) decarbonisation. Questions that can be answered include: - What is the most efficient way to achieve a given greenhouse gas reduction target? - Which technologies could play a role? - What costs result from specific policy targets? As input, the model requires characteristics of a large number of technologies and assumptions on various long-term developments in the Dutch energy system. It is regularly used for research projects of PBL andTNO.
Scale	National (The Netherlands)
Timescale	Optimisation for a year in the future (e.g. 2050), based on a time slice representation of hours of the year.
Applications	- The model allows to develop cost-optimal long-term climate strategies. - OPERA orders options from lowest to highest costs per ton of CO_2 to produce national marginal abatement cost curves.
Limitations	- Long calculation times lead to limitations on technology detail, geographical differentiation, sector differentiation and time resolution. - Long-term (technology) developments are highly uncertain.
Reference	- Bert Daniëls, *Korte modelbeschrijving Option Portfolio for Emission Reduction Assessment (OPERA)*, PBL, 2019.[41] - *Verkenning van klimaatdoelen, Van lange termijn beelden naar korte termijn actie*, Policy Brief, Jan Ros (PBL) en Bert Daniëls (ECN), 2017.[42]

[41] https://www.pbl.nl/sites/default/files/downloads/pbl-2019-korte-modelomschrijving-opera_3838.pdf

[42] http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2017-verkenning-van-klimaatdoelen-van-lange-termijnbeelden-naar-korte-termijn-actie-2966.pdf

A.10 Orchestrating Energy Transitions (Orchestrating Innovation Model)

Name	Orchestrating Energy Transitions (Orchestrating Innovation Model)
Type	Social Models & Stakeholder Approaches
Developer	TNO
Short description	To realize successful energy transitions it is important to take multiple perspectives into account: business, technical, social and governance. The "Orchestrating Energy transitions" approach is based on the Orchestrating Innovation Model and consists of six steps, starting from defining an ambition and ending with monitoring the results in practice. In each step the four perspectives are taken into account. For each step of the approach knowledge and tools are provided to enable decision making and preparation to proceed to the next step. Multiple steps of the approach have already been applied in several municipalities. The approach can be used as overall approach for transforming local regions. The approach links with the Stakeholder Engagement for Energy (SEE) approach which supports municipalities in collaborating with stakeholders during all steps of the energy transition.
Scale	Neighbourhood, district, city, region, province
Timescale	
Applications	- Parts of the approach have already successfully been used in The Hague and in Houten. - The approach provides guidance and support via multiple tools.
Limitations	Although parts of the approach have been successfully applied, the complete approach has not yet been applied.
Reference	Guus Mulder, Nicole de Koning, Alexander Woestenburg and Anita Lieverdink, *Orchestrating Energy Transitions*, 2016 (presentation).

A.11 Process Energy Neutral Business Parks BE+

Name	Process Energy Neutral Business Parks BE+
Type	Dedicated Models
Developer	TNO, OostNL, WM3, Kortman Parkmanagement
Short description	This tool describes the steps towards an energy neutral business park. For each step tools have been developed to support this step. Also a training is developed to train park management in this process. The process has been developed in practice with organizations that support business parks. The process is used in practice in the business parks that participate in 'Bedrijventerreinen Energiepositief' (BE+).
Scale	Neighbourhoods (specifically business parks)
Timescale	Years
Applications	- Business parks are important to realise a sustainable built environment, which is largely neglected in tools and policy. - The process is a practical tool that has been developed in practice.
Limitations	- The process is focused on a specific target group: park management organizations. - Even the optimized process takes a lot of effort for which finance is hard to obtain. These costs do have a return on investment, but because of uncertainty and duration of the process in practice this is mostly covered by subsidies.
Reference	https://www.bepositief.nl/

A.12 Quick Guide Energy Project on Business Parks

Name	Quick Guide Energy Project on Business Parks (Snelstartgids Duurzame Energie op Bedrijventerreinen)
Type	Dedicated Models
Developer	TNO, IVAM, Engie, Markus Makelaardij, ECWF, Klapwijk Parkmanagement
Short description	This guide will help park managers to take the steps necessary to work with sustainable energy measures on a business park. The target group of this Quick Guide is not only the park manager, but also the business association or other regional organization on the business park. The Quick Guide describes the different steps of the communal decision-making process. For each step the guide describes how a park management organization can be supported. The guide also contains a set of tools. It has been developed in practice with organizations that support business parks. The guide is based on desk research, interviews with park managers, a survey with businesses situated on industrial parks and three pilot projects.
Scale	Neighbourhoods (specifically business parks)
Timescale	Years
Applications	- Business parks are an important part in realizing a sustainable built environment, which is largely neglected in tools and policy. - The Quick Guide is a practical tool that has been developed in practice.
Limitations	- The Quick Guide is focused on a specific target group: park management organizations. - Even the optimized process takes a lot of effort for which finance is hard to obtain. These costs do have a return on investment, but because of uncertainty and duration of the process in practice this is mostly covered by subsidies.
Reference	https://www.bepositief.nl/

A.13 Quick Guide The Sustainable Home Owner Association

Name	Quick Guide The Sustainable Home Owner Association (De Duurzame VvE: quick guide)
Type	Dedicated Models
Developer	TNO, LENS, vb&t, VvE Metea
Short description	Of Dutch dwellings, 25% is collectively owned and by law governed by a home owner association. This means that for most sustainable home improvements - such as solar panels, insulation, and LED lighting- a communal decision needs to be made. The Quick Guide supports all organizations who want to help home owner associations to apply sustainable home improvements. The Quick Guides describes the different steps of the communal decision-making process. For each step the quick guide describes how a home owner association can be supported. The guide also contains also a set of tools. It has been developed in practice with organizations that support home owner associations. The guide is based on desk research, interviews with chairmen of home owner associations and experiences in practice.
Scale	Home owner associations (within neighborhoods)
Timescale	-
Applications	- The Quick Guide is focused on a specific target group: home owner associations. Home owner associations are an important stakeholder in realizing a sustainable built environment. - The Quick Guide is a practical tool that has been developed in practice.
Limitations	
Reference	- De Duurzame VvE: quick guide[43] - https://www.tno.nl/nl/over-tno/nieuws/2017/10/stimulans-vve-s-voor-verduurzamen-woningen/ -

[43] https://www.tno.nl/media/10352/stem-de-duurzame-vve-quick-guide.pdf

A.14 Routeplanner Energieneutraal

Name	Routeplanner Energieneutraal
Type	General Energy System Models
Developer	TNO and GEN consortium
Short description	The Routeplanner provides a description of steps to be taken from first formulation of an ambition towards energy system design and design of business model to make energy transition affordable for everyone. It can be used as a guideline for an integral approach.
Scale	Districts (1,000 – 5,000 dwellings), urban environment
Timescale	Years
Applications	- Development is based on real cases (new built and existing areas) (Apeldoorn and Katwijk) and elaborated through TKI Smart Energy Cities. - Takes into account the governance and spatial process. - Mainly qualitative. - Well aligned trade-off between measures on district and building level. - Takes into account the lowest cost for households.
Limitations	- Limited level of detail. - Does not support the decision making (it refers to tools like that, but it is not included). - Does not take into account the regional or national level. - Designed by big corporates and thus built upon that perspective.
Reference	Gebieden Energie Neutraal, *Routeplanner Nieuwbouw; Toelichting*, 2018.[44]

[44] https://www.smartenergycities.nl/wp-content/uploads/2018/05/T1_GEN_1_NB_Routeplanner_Toelichting.pdf

A.15 Social Site Characterisation (SSC)

Name	Social Site Characterisation (SSC)
Type	Social Models & Stakeholder Approaches
Developer	EU FP7 SiteChar project
Short description	SSC is a method to map the social context of a site and to guide development of effective local stakeholder communication and engagement. It involves both qualitative and quantitative research activities such as desk research, stakeholder interviews, media analyses, and surveys. The aim of SSC is to identify: – stakeholders or interested parties; – factors that may drive their perceptions of and attitudes towards prospective site developments. This knowledge can subsequently be used to develop tailored local communication and public engagement exercises. The method has been developed and tested within the SiteChar project. It is based on scientifically sound research methods and theory on public engagement.
Scale	Region
Timescale	-
Applications	SSC allows to discuss complex processes with a lay audience, to create a ‘safe space’ for exchange of thoughts on plans for the region and to gather insights into stakeholder perceptions and effective communication.
Limitations	- A general challenge in using participatory methods is to reach agreement on the goal of the participation and a definition of the ‘desirable’ outcome. - Participants in SSC have to invest a lot of time and effort, but this does not guarantee that their vision will have an impact on the final (political) decisions regarding a regional development. Disappointment about this can be a source of conflict.
Reference	Suzanne Brunsting, Jessanne Mastop, Marta Kaiser, René Zimmer, Simon Shackley, Leslie Mabon and Rhys Howell, *CCS Acceptability: Social Site Characterization and Advancing Awareness at Prospective Storage Sites in Poland and Scotland*, Oil & Gas Science and Technology – Rev. IFP Energies nouvelles, Vol. 70 (2015), No. 4, pp. 767–784.[45]

[45] https://ogst.ifpenergiesnouvelles.fr/articles/ogst/abs/2015/04/ogst130247/ogst130247.html

A.16 Stakeholder Engagement for Energy (SEE)

Name	Stakeholder Engagement for Energy (SEE)
Type	Social Models & Stakeholder Approaches
Developer	TNO
Short description	Local energy transitions are challenging. Municipalities play a key role but cannot do it on their own. Smart collaboration is needed: working together with the right stakeholders, at the right moment, in the right way within the right conditions. SEE is an approach for collaboration with stakeholders during a local energy transition process. The SEE approach contains many practical tools. It has been developed for municipalities but can also be used by other organizations. SEE is based on desk research and experiences from municipalities in practice. It links with the Orchestrating Innovation (OI) model, which describes six steps of a local energy transition.
Scale	Neighbourhood, district, city, region, province
Timescale	-
Applications	- Collaborating with stakeholders is an essential element for realizing successful energy transitions. Local energy transitions however have specific properties and there are only few approaches available specifically for stakeholder collaboration in the energy transition. - Many municipalities have difficulties in collaborating with stakeholders. How can you engage stakeholders? How can you build on existing initiatives? When do you start working together with stakeholders? Which forms of collaborations are suitable in which situation?
Limitations	Some of the tools of the approach have not yet been used in practice.
Reference	Nicole de Koning and Pepijn Vos, "*Lokale energietransitie: samen aan de slag - een systematische aanpak voor 'Stakeholder engagement for energy' (SEE)*", TNO, 2017 (presentation).

A.17 Study Energy Islands

Name	Study Energy Islands (Studie energie-eilanden)
Type	Dedicated Models
Developer	ECN
Short description	The study provides insight into the balance between supply and demand of electricity while increasing use of the North Sea offshore-wind potential. The study was commissioned by Gasunie. The study uses an Excel model based on the electricity market model COMPETES. Required input include: electricity demand; hourly demand profiles; generation options and capacities for electricity, and energy and CO_2-prices for North Sea countries. Further study in more detail with the electricity market model COMPETES can provide an instrument for streamlining stakeholder debate through joint and structured development of model input. The tool can provide general insights that can support visions.
Scale	North Sea region
Timescale	Hourly
Applications	- Obtain insight in the balance between supply and demand of electricity in the event of large-scale development of offshore wind on the North Sea. - Indications of possibilities for production of hydrogen, and the cost of hydrogen production, and pipeline infrastructure.
Limitations	Specific expert tool.
Reference	Marcel Weeda and Marit van Hout, *Verkenning Energie-functionaliteit Energie Eilanden Noordzee*, ECN, 2017.[46]

[46] https://publicaties.ecn.nl/ECN-E--17-064

A.18 Target Energy System (TES) Methodology

Name	Target Energy System (TES) Methodology
Type	Social Models & Stakeholder Approaches
Developer	TNO
Short description	The TES methodology helps to assess possible future solutions for the energy transition. It comprises a process/workflow to define the ambitions with the involved stakeholders and to define the boundaries of the solution space, and a calculation model to assess the impact of all required choices. The methodology requires some information about the region: demography; current (yearly) energy usage (electricity, gas, heat) of different sectors; building stock; mobility needs; and specifics of the surrounding region and possible sources of energy. It results in several scenarios that fit the ambitions of the stakeholders. Scenarios can be compared using approximately 15 key performance indicators covering both environmental aspects, financial aspects and social aspects. The methodology has been applied in practice in two commercial projects on neighbourhood and regional scale.
Scale	The methodology has been developed with the scale of neighbourhoods, cities or regions in mind, although provinces could be considered too.
Timescale	Most of the calculations are performed using yearly data, but for the calculation of required storage in the future energy system, generic profiles with more detailed timescales are used (15 minutes).
Applications	- One of the applications was in a region with several small cities and villages, with a large agricultural area in between, where several scenarios for the target energy system were assessed. - Certain trends in relevant parameters for the model were assumed (number of inhabitants, energy usage, mobility needs). - Several scenarios were defined jointly based on regional possibilities (among others taking into account biogas potential based on agricultural data and yearly sewage information, the potential role of cooling houses in the energy system, the option to become a mobility hub for a neighbouring large city, combining electric vehicle charging possibilities with high speed public transport).
Limitations	- Assumes certain trends in the change of used figures, so conclusions should always be interpreted with care. - Only gives insights in total system costs (no costs per stakeholder). - Methodology relies on a lot of ball park figures (investment costs and potential energy yield per technology option, embodied CO_2 data): figures must be continuously updated with data from the field.
Reference	-

A.19 Urban Learning Cycle

Name	Urban Learning Cycle
Type	Integrated Approaches
Developer	TNO
Short description	The Urban Learning Cycle improves urban policy and decision making. It is a methodology to get in-depth insight in the entire urban policy making cycle. Through this methodology policy makers become aware of the interlinkages between policy stages and different knowledge demands in each stage. The Urban Learning Cycle not only provides the answer to the challenge of closing the cycle, it also provides clues on how to deal with the main challenges of urban policy making: cross-domain integration, organizational integration, dealing with decision making contexts and developing local innovation ecosystems. Application of the methodology requires several workshops with different stakeholders within the public body. The Urban Learning Cycle methodology has been applied in different cities and is well embedded within scientific public administration literature.
Scale	All scales
Timescale	Policy cycles (usually a few year)
Applications	- Qualitative improvement of policy processes and policy outcomes - In-depth insight in missing links and missing knowledge to improve urban policy - Practical clues to deal with major challenges regarding urban policy making
Limitations	Holistic and integrated view; takes time and engagement of many relevant stakeholders to actually improve policy making.
Reference	-

A.20 Value-based Experience Framework

Name	Value-based Experience Framework
Type	Social Models & Stakeholder Approaches
Developer	TNO
Short description	Initiatives to promote energy transition would benefit from a holistic approach that acknowledges a system's overall capacity, willingness and affordances towards change (besides creating the preconditions for change). TNO developed a design-oriented quadruple helix approach to energy transition based on a value-based framework that addresses willingness and ability to change by incorporating the value system of each involved stakeholder. The approach establishes common ground and a shared vision towards transition-related outcomes by enhancing trust and cohesion in the participatory design process. The approach has been applied in different projects. It is based on scientific literature.
Scale	Neighbourhood, district, city, region
Timescale	-
Applications	- Preliminary results from using the approach indicate the prevalence of different conflicting values, interests and concerns between stakeholders, as well as within stakeholders. - Addressing these conflicts at the right time and through collaboration has been identified as fruitful, leading to more successful transition processes, within a shorter time period, with better relationships between stakeholders and a higher stakeholder satisfaction about the process as well as the results. - Trust, between stakeholders during collaboration, in the process itself and in the future outcomes in terms of effects on values are key to successful transitions.
Limitations	The experience with this approach in the energy domain is still limited.
Reference	Joke Kort, Nicole de Koning and Charlie Gullström Hughes, *Creating successful transitions in energy, By respecting stakeholder values and securing trust and cohesion*, Energy-Open, 2017[47]

[47] https://energy-open.nl/local/abstracts/024_kort.pdf