# CCS roadmap preparation

## Analysis of roadmaps related to energy and environmental technologies

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# 1 Executive Summary (restricted)

A main goal in WP2.4 is to prepare a CCS roadmap for the Netherlands. Stefanie van de Water of the technical university Eindhoven (Sustainable Energy Technology, specialization Energy and Society) performed a study to the aims, structure and characteristics of technology roadmaps. The results of this study will be used to better structure the CATO CCS roadmap for the Netherlands.

In this research, roadmaps related to energy and environmental technologies are analysed. The main aim was to get insight into the characteristics of these kinds of roadmaps to make recommendations for a roadmap on carbon capture and storage (CCS) in the Netherlands. Fifteen roadmaps are selected. The technologies considered are CCS, hydrogen technology and geothermal energy technology. Hydrogen and geothermal technologies were chosen because they have similarities with CCS. The selected roadmaps were reviewed and the following characteristics were determined: the purpose of the roadmap, the methodology applied the structure of the roadmap, the topics and themes covered, the stakeholders involved, the target audience of the roadmap, the initiator of the roadmap, the timeframe and scope of the roadmap.
It was found that most roadmaps have a national scope. They are often made by or in order of governments or by institutions. Roadmaps can be aimed at especially governments or technically educated people, but often roadmaps are directed to all relevant stakeholders. The timeframe of the roadmaps is a few decades, with exception of the actions formulated. These are more near term. Based on the analysis four types of purposes were found: to determine strategy, to bring stakeholders together, to convince stakeholders and to provide information. Especially the aim to convince stakeholders was found to be important. The technologies considered are not widely deployed yet. Therefore advocates such technology search for support. Because often no agreements are made by stakeholders on the strategy, there is little pressure for executing the strategies proposed.
Before making a CCS roadmap for the Netherlands it purpose should be clear and it should be determined whether a roadmap is the right type of document to fulfil this purpose. It was found that the purpose, target audience and topics covered were closely related. When the purpose is determined the target audience of the roadmap and the topics which should be covered also become clear.

# Distribution List

(this section shows the initial distribution list)

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# Document Change Record

(this section shows the historical versions, with a short description of the updates)

| Version | Nr of pages | Short description of change | Pages |
|---|---|---|---|
| See header | 1 - xx | First version | |
| | | | |

# Table of Content

# 2 Applicable/Reference documents and Abbreviations

## 2.1 Applicable Documents

(Applicable Documents, including their version, are the “legal” basis to the work performed)

| | Title | Doc nr | Version |
|---|---|---|---|
| AD-01d | Toezegging CATO-2b | FES10036GXDU | 2010.08.05 |
| AD-01f | Besluit wijziging project CATO2b | FES1003AQ1FU | 2010.09.21 |
| AD-02a | Consortium Agreement | CATO-2-CA | 2009.09.07 |
| AD-02b | CATO-2 Consortium Agreement | CATO-2-CA | 2010.09.09 |
| AD-03g | Program Plan 2013b | CATO2-WP0.A-D03 | 2013.04.01 |
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## 2.2 Reference Documents

(Reference Documents are referred to in the document)

| | Title | Doc nr | Version |
|---|---|---|---|
| RD-01 | | | |
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## 2.3 Abbreviations

(this refers to abbreviations used in this document)

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# 3 Introduction

## 3.1 Background

Since the mid 20th century the temperature of the atmosphere is increasing significantly. An increase in temperature affects many biological systems. According to the International Panel on Climate Change it is *"very likely"* that the increase in global average temperatures is caused by the increase of anthropogenic greenhouse gas emissions.[1] Carbon dioxide is considered to be the most important anthropogenic greenhouse gas. Because of the negative effects of global warming, efforts are made by companies and governments to reduce the amount of carbon dioxide which is released into the atmosphere.

Renewable energy technologies have been developed because a large part of the $CO_2$ emissions is caused by burning fossil fuels. Since the beginning of this century there also has been an increasing interest in carbon capture and storage (CCS). It is expected that fossil fuels will stay an important source of energy and CCS is the only way to reduce the $CO_2$ emissions to the atmosphere resulting from the use of these fossil energy sources. Carbon capture and storage is now seen as one of the solutions to mitigate climate change. According to some parties this technology will even be indispensable to achieve certain climate mitigation goals. [2] For this reason, countries such as the United States, Canada and several European countries stimulate the research, development and implementation of CCS.

Also in the Netherlands there has been an increasing interest in carbon capture and storage. Research into CCS technologies in the Netherlands started in the 1980s at the University of Utrecht. The studies conducted were often relatively small. When money became available for financing a larger scale research project, the CATO project was initiated. [3] In the CATO project many stakeholders were involved, including universities, research institutions, NGO's, industry and the Dutch government. The project started in 2004 and ended in 2008. It was considered successful and it was decided that there should be a follow up project: the CATO-2 project.[4]

The CATO-2 project builds upon the CATO-1 project. Where the character of the CATO-1 project was explorative, the CATO-2 project is more application oriented. The budget for CATO-2 is much larger compared to the budget for the CATO-1 project and approximately 40 stakeholders are involved.[3]

The CATO-2 project is divided into six different themes: capture; $CO_2$ transport and chain integration; underground storage, monitoring and verification; regulation and safety; public perception; knowledge, education, dissemination and transfer.[4] Within the theme $CO_2$ transport and chain integration the longer-term development and implementation of CCS in the Netherlands is studied. As part of this study an implementation plan, including a roadmap, will be designed.[3]

## 3.2 Rationale

Technology roadmapping is a flexible technique used by industry, governments and institutions for long-term strategy and technology planning. Because the technique is flexible, there exists a wide variety of roadmaps. Not only the methodologies applied differ, also the purposes and the subjects included vary. There are no standards or protocols for the construction of roadmaps. On the one hand this is an advantage, because the organization which sets up a roadmap can adapt the approach so that it fits the goals of the organization. On the other hand this broad variety can also lead to difficulties applying the method. Companies often "re-invent" the process. [5]

During the construction of the roadmap for CCS in the Netherlands, the difficulties and possibilities related to this flexibility are also encountered. Also in this case, the roadmapping process was tailor made, a methodology was set up. First a consistent vision was developed through stakeholder workshops. Then, stakeholders identified the actions which were needed to achieve this vision as well as possible barriers and challenges. This led to valuable information, which will be used as input for the roadmap.

The roadmap which is going to be made can have different characteristics. Dependent on the purpose and the audience of a roadmap, decisions should be made about for example the structure and the

scope of the roadmap and the topics covered by the roadmap. It would be helpful for the authors of this implementation plan to get some insights into the characteristics of other environmental and energy related technology roadmaps. Therefore a set of roadmaps will be reviewed, so that clear recommendations can be formulated for the development of a roadmap for CCS in the Netherlands.

## 3.3 Research questions

As introduced above an implementation plan including a roadmap will be made as part of the CATO-2 project. The goal of this research will be to make recommendations for developing a suitable roadmap for CCS in the Netherlands and to make an overview of the characteristics of existing roadmaps. The study will limit itself to roadmaps of environmental or energy related technologies. The research question will be twofold.
*What are the main characteristics of energy and environmental related technology roadmaps?*
*How can the insight in characteristics be applied, be translated into recommendations for making a suitable roadmap for CCS in the Netherlands?*
By answering the first research question more insight is gained about *how energy and environmental related roadmaps are used for communication* between governments, institutions, companies and other stakeholders. The first research question will be answered by looking into certain characteristics of roadmaps. The subquestions show which characteristics will be considered.

- *What is in general the purpose of energy and environmental oriented roadmaps?*
- *What methodologies are applied in the roadmapping processes?*
- *What is in general the structure of energy and environmental oriented roadmaps?*
- *What topics and themes do energy and environmental oriented roadmaps cover?*
- *Who are involved in composing the roadmaps and in what way are these stakeholders involved?*
- *What is the target audience of the roadmaps?*
- *Who is the "sender" of the roadmap? Who is communicating through the roadmap?*
- *What is the timeframe of energy and environmental oriented roadmaps?*
- *What is in general the scope of energy and environmental oriented roadmaps?*
- *How do the above mentioned characteristics of roadmaps relate to each other? Is it possible to make a categorization, or schematization of these roadmaps?*

Beside these characteristics, the characteristics of certain technologies as well as the state of development of the technology should be kept in mind. Also the publication date and whether the roadmap is updated can be of importance. Other characteristics not mentioned in the sub questions will be mentioned separately when these are noticeable.

## 3.4 Outline

First theory about technology foresight and roadmapping will be explained. This provides more background and understanding of technology roadmapping and other methods used. Also useful findings of previous research will be discussed. Then it will be explained how the roadmaps will be reviewed and which roadmaps are selected for this study. The results and discussion follow. The report ends with the conclusion in which the research questions are answered and recommendations are made.

# 4 Related literature and studies

In this chapter more background is given about technology roadmapping. First, future studies are described and the role of roadmapping within this field. Then some findings from previous research are discussed.

## 4.1 Roadmapping as a future study

To cope with the future, studies are done with the aim to 'explore' or even predict the future. This is especially important for industry and governments to determine strategy and to develop policies. There exist different types of future studies. Although the different types partly overlap, a distinction can be made between technology forecasting, technology foresight and technology assessment. In technology forecasting, technology developments are continuously monitored. Trendlines are extrapolated to forecast the development of a technique as closely as possible. In the second type, technology foresight, technological trends as well as societal issues are included. This approach is therefore much broader. The aim is not to predict the future but to identify possible future trends. The third type, technology assessment, focuses on the societal effects and impact of technologies.[5] Within technology forecasting and foresight another more specific categorization is made by McDowall, which gives insight into roadmapping as a future study. McDowall made a review of the hydrogen futures literature. His aim was to get an overview of the diversity of current hydrogen futures. Six types of (hydrogen) future studies were identified. These are forecasts, exploratory scenarios, technical scenarios, visions, backcasts/pathways and roadmaps. Also for these types of studies, the distinction is gradual. The definitions can be seen in table 1. Forecasts, exploratory scenarios and technical scenarios are descriptive approaches. In these approaches 'likely' or plausible futures are predicted. These futures are not always desirable. Visions, backcasts/pathways and roadmaps are normative studies. In these studies a desirable future is defined as well as possible pathways to this future.[6,7]

*Table 1: The six types of future studies identified by McDowall,* ***adopted from [7]***

| | |
|---|---|
| Descriptive | **Forecasts** use formal quantitative extrapolation and modelling to predict 'likely' futures from current trends. |
| | **Exploratory Scenarios** explore possible futures. They emphasize drivers, and do not specify a predetermined desirable end state towards which storylines must progress. |
| | **Technical Scenarios** explore possible future technological systems based on hydrogen. They emphasize the technical feasibility and implications of different options, rather than exploring how different futures might unfold. |
| Normative | **Visions** are elaborations of a desirable and (more or less) plausible future. They emphasize the benefits of hydrogen, rather than the pathways through which a hydrogen future might be achieved. |
| | **Backcasts** and **pathways** start by defining a desirable and plausible future end point. They then investigate possible pathways to that point. |
| | **Roadmaps** describe a sequence of measures designed to bring about a desirable future. Studies from the previous five groups, or elements of these groups, sometimes form the basis for the identification of specific measures. |

This study focuses on roadmaps, which are normative. The three normative types of future predictions are close together. In all three types, a hydrogen economy is seen as desirable. In the roadmaps, a vision as well as a series of actions, steps to achieve this vision are included. This vision however is only described in goals, in targets, or actions which should be taken, but not in an explicit or narrative way. In the backcasting/pathway and vision future studies, the future vision is explained more extensively. Sometimes the terms 'roadmap' and 'vision' are used interchangeably. A vision can be a document in which it is elaborated how a hydrogen future will look like. Another type of 'vision', which McDowall categorizes under roadmap, is a vision which serves as a basis for the roadmapping process and which is produced during stakeholder workshops. So although a distinction is made between these three normative types of future studies, the difference can be very small in some cases.[6,7] This should be kept in mind when searching for and analysing roadmaps.

## 4.2 Characteristics technology roadmapping in previous research

There are multiple studies in which roadmaps are reviewed. In a study performed for the Dutch Ministry of Economic Affairs, "The effectiveness of technology roadmapping", a large amount of supra-company level roadmaps were reviewed. The collection of roadmaps considered were mainly from Canada, the US, Europe and Japan, but covered a broad range of industries. The aim of the study was to examine the usefulness of technology roadmapping for the Dutch innovation system.[8] In another study, by Amer and Daim, the focus was on roadmaps for the renewable energy sector. A large amount of renewable energy roadmaps was reviewed and categorized.[9] In the studies of McDowall, already partly addressed above, hydrogen futures and roadmaps were reviewed.[6,7,10] Last mentioned studies differ from the study for the Dutch Ministry of Economic Affairs. The roadmaps considered in the studies of Amer, Daim and McDowall are on renewable technologies which are not widely deployed yet. The roadmaps considered in the study of the Dutch Ministry of Economic Affairs are industry roadmaps. Nevertheless, the findings of all four researches will be discussed in this section.

*Purposes of roadmaps*

In all studies possible purposes of roadmaps are mentioned. McDowall identifies three important aims of hydrogen roadmaps: 1. To identify barriers to the emergence of a hydrogen future and measures to overcome them; 2. To demonstrate and convince others of the potential of hydrogen; 3. To develop a shared vision and shared strategies by bringing stakeholders together. [6,7]

In the study executed for the Dutch Ministry of Economic Affairs, focusing on more technical supra-company level roadmaps, two important purposes were distinguished: the "research priorities-model" and the "research needs-model". In the "research needs-model" all possible research needs are identified, whereas in the "research priorities-model" it is determined which research has to be executed to achieve certain goals, realize a vision. Often these type of roadmaps, especially from the US, are aimed to qualify for funding of the government. Also to connect or align public and private research was seen as a goal of the roadmapping exercises. Furthermore it was found that in Japan, roadmaps are sometimes used to determine regulations and codes. [8]

The paper written by Amer and Daim, goes deeper into the purpose of roadmaps and focuses on renewable energy technology roadmaps. A categorization is made distinguishing national, industry/sector and organizational level roadmaps. National level roadmaps focus on issues such as energy security and dependence, the protection of the environment and energy policies. Industry sector level roadmaps focus on establishing a common vision and identifying barriers and needs. These roadmaps are constructed by for example industry associations, government departments, or national research laboratories. The third type of roadmaps is organizational roadmaps, which focus on R&D and business goals, often on product level. These roadmaps are made by companies and are meant for internal use. For all three types of roadmaps, an extensive list of objectives was given, which can be found in appendix A.[9]

*Initiator of roadmaps*

Also the initiators of the road mapping process or the organizations that develop these roadmaps are identified. In the paper of Amer and Daim NGOs, academia, industrial associations, community

groups, environmental organizations, governmental organizations, government departments and national research laboratories are mentioned as organizations which initiate and develop national and industrial level roadmaps on renewable energy.[9] For more industrial roadmaps, the supra-company level roadmaps, studied in the report for the Dutch Ministry of Economy Affairs, government, industrial research institutions and companywide organizations found to be initiators.[8]

*Methodology applied and stakeholders involved*
McDowall mentions that "building a roadmap usually involves groups of stakeholders identifying the drivers, barriers, targets, and wider threats and opportunities."[6,7] Amer and Daim list more detailed which methods are used for each type of roadmap and give an indication of how frequently these methods are used. In national level roadmaps and industry level roadmaps scenario based planning is used often. Other methods which are used are SWOT analysis, Delphi, expert panels, risk assessment and PEST analysis. Patent analysis and citation network analysis are almost never applied.[9]

*Timeframe of roadmaps*
Amer and Daim find that the timeframe of roadmaps varies from 10-50 years. There is a difference between national and industrial level roadmaps and organizational level roadmaps. Organization level roadmaps have shorter timeframes, while national/industry level roadmaps focus on larger time frames.[9] McDowall notices for hydrogen technology roadmaps that the timeframe of the policies are more near-term: 5-10 years, whereas the targets are more longer term: up to 2050 and beyond.[6,7] The above mentioned characteristics are part of the research framework which will be discussed in the next chapter.

# 5 Methodology

The methodology consists of three steps. First, an overview of existing roadmaps is made. From the collection of roadmaps found, a selection of roadmaps is made for the study. The third step is reviewing the selection of roadmaps to determine the characteristics.

## 5.1 Overview of energy and environmental related technology roadmaps

An overview of energy and environmental related technology roadmaps was made. This overview serves two purposes. The overview is needed to make reasoned choices which roadmaps are going to be studied and which are not. In addition to that, the overview can already give some ideas about the characteristics of roadmaps. The list of roadmaps can be found in the appendix. Most of the roadmaps were found using a search engine, Google. The terms used when searching were "roadmap" and one of the key words of the corresponding technology like "solar", "wind" and "hydrogen". Also existing lists of roadmaps were used.[11, 12, 13] The following technologies were considered: solar photovoltaic; wind energy; hydrogen energy; carbon capture and storage; biomass; smart grids and geothermal energy. Other energy and environmental related technologies, such as concentrated solar power, electric vehicles, and energy efficient buildings were left out.

## 5.2 Selection of roadmaps relevant for CCS

From the large set of roadmaps found, a selection was made. It was decided to select roadmaps of technologies which are comparable to CCS and roadmaps of CCS itself. Because the aim of this study is to make recommendations for a CCS roadmap, it will be more useful to get insights in these kinds of roadmaps. Furthermore there seem to be already significant differences between roadmaps of one specific technology.
The technologies which are going to be considered are CCS, hydrogen technology and geothermal energy. Geothermal is chosen because the technology is not mature and profitable yet. Investment costs are high and it involves drilling. Therefore the government plays an important role for this technology. Hydrogen technology roadmaps were chosen because the cooperation between the

government and industry is also very important for this technology. Furthermore, the technology is approximately in the same phase as CCS. Both technologies are not widely deployed yet. Also the scale of the technology is comparable. Both technologies need a new or change in infrastructure. The selection of technology roadmaps which is going to be studied is shown below.

- **CCS Roadmap, supporting deployment of Carbon Capture and Storage in the UK (2012)**
  Department of Energy and Climate Change United Kingdom

- **DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap (2010)**
  DOE/NETL - National Energy Technology Laboratory, United States Department of Energy

- **CCSTRM Canada's $CO_2$ Capture & Storage Technology Roadmap (2006)**
  Natural Resources Canada

- **Technology Roadmap, Carbon capture and storage (2010)**
  IEA, International Energy Agency

- **Insuring Energy Independence, A CCS Roadmap for Poland (2011)**
  BEST, Bellona Environmental CCS team

- **Hydrogen and Fuel Cells: A Vision of Our Future (2003)**
  European Commission

- **The Icelandic Hydrogen Energy Roadmap (2004)**
  Prepared for the Icelandic Ministry of industry and commerce

- **Hydrogen Technology Roadmap (2008)**
  Wyld Group, prepared for the Australian Government

- **Hyways, European Hydrogen Energy Roadmap (and Action Plan for the Roadmap) (2008)**
  Project Coordinator: Ludwig- Bölkow-Systemtechnik GmbH

- **National Hydrogen Energy Roadmap (2002)**
  NETL, DOE - National Energy Technology Laboratory, United States Department of Energy

- **Texas Hydrogen Roadmap (2009)**
  HARC - Houston Advanced Research Center

- **Technology Roadmap, Geothermal Heat and Power (2011)**
  IEA - International Energy Agency

- **Australian Geothermal Industry Development Framework (2008)**
  Australian Government, Department of Resources, Energy and Tourism

- **Australian Geothermal Industry Technology roadmap (2008)**
  Australian Government, Department of Resources, Energy and Tourism

- **Canadian Geothermal Heat Pump Industry Technology Roadmap (2012)**
  Canadian GeoExchange Coalition

## 5.3 Determining characteristics of the selection

The characteristics of this selection of roadmaps were determined. This was done by reviewing and analysing the roadmaps separately. Sentences or parts of the text from which the characteristics become clear are quoted. The following characteristics were considered:

- *Purpose*

When describing the purpose of the roadmaps, both the purpose of the roadmapping process and that of the document are considered. When the purpose of the roadmap is not mentioned explicitly in the introduction, it is deduced from other text fragments and the organization which communicates through the roadmap.

- *Methodology*

  Each roadmap is made in a different way, all roadmapping processes differ from each other. It is investigated in which way the information is obtained.

- *Structure*

  When describing the structure of the roadmap, it is studied in which order different parts of the report are treated.

- *Topics and themes*

  Different topics and themes can be addressed. In some roadmaps the focus will be on technical R&D while other roadmaps focus more on policy and regulations. The topics and themes addressed in the roadmap will be described as well as the extent to which these topic and themes are covered.

- *Involvement stakeholders*

  Another important issue is the involvement of stakeholders during the process itself. It will be described which stakeholders were involved during the process and in which way these stakeholders are involved.

- *Target audience*

  The target group or target audience of the roadmap will be determined as accurate as possible. When the target audience is not mentioned in the introduction, the target audience of the roadmap will be deduced from the actions and information given in the roadmap: for whom are the actions meant? For which parties might the information given in the roadmap be useful?

- *Sender*

  When a roadmap is meant to carry out a message, there will be a 'sender' or initiator of the roadmap. It will be described, who is communicating through the roadmap.

- *Timeframe*

  The timeframes of roadmaps can differ. In some roadmaps the focus will be on the near future whereas in other roadmaps several decades are considered.

- *Scope*

  When describing the scope, the geographical scope is meant.

# 6 Results and discussion

## 6.1 General impression of roadmaps

First an overview of roadmaps was made. Some difficulties and restrictions were encountered when searching for roadmaps. Because the key terms used for searching are English, most roadmaps found are written in English and made for 'developed' countries. Also the boundary between what can be called a roadmap and what cannot is rather unclear. Some documents were called roadmaps, but the contents of these documents did not correspond to what is understood as a roadmap as explained in chapter 2 using the categorisation of McDowall. [6,7] Sometimes only a vision was given but no steps to achieve this vision and some roadmaps only showed the potential for renewable energy sources in a country. In this study only English roadmaps are considered and the document should include a sort of future, and a path towards that future.

The amount of roadmaps for each technology which can be found varies. For solar PV, and hydrogen technology a lot of roadmaps were found, whereas the amount of roadmaps for wind energy and geothermal energy was small. In another study performed, it was also found that the number of hydrogen and solar energy technology roadmaps is high. The reason put forward for this is that the amount of technology roadmaps developed is closely related to the interest in this technique, to the intensity of research, development and deployment activities.[9]
Most roadmaps found have the form of a report. There were also some presentations and slides of roadmaps but in most cases these belonged to the report. The documents found are digitally available. Websites themselves however, seem to be used seldom for presenting and updating a roadmap. Often only a small introduction and a link to the document are given. Even when a website was set up for a roadmap (such as http://www.roadmap2050.eu/, http://www.itrpv.net/ and http://www.tonga-energy.to/?page_id=2), roadmaps were still communicated through reports and not through the website itself. A website seems however a suitable medium to present roadmaps, because of the possibility of updating roadmaps and discussing them. Nevertheless, in this study only written reports will be considered.
Renewable energy roadmaps are mainly written by, or in order of governments and institutions. Roadmaps on solar energy were more often made by industry associations, while roadmaps for other technologies are written by organizations which are closer related to governments. The initiators of nuclear energy and smart grid roadmaps also differed. Next to governments these roadmaps were also initiated by research institutions and nuclear power industry for nuclear energy and network operators for smart grids. But the vast majority of roadmaps are developed by governments and governmental institutions.
The purpose of the roadmaps also varies slightly for different technologies. This seems to be related to the maturity of a technology. Roadmaps on solar photovoltaic seemed to focus more on research directions and cost reductions, sometimes supplemented by policy measures needed for a more large scale implementation of solar PV. Roadmaps on nuclear fission mainly focussed on technical issues and R&D or on nuclear waste, acceleration transmutation of waste. The focus of less mature technologies seem to be more on convincing stakeholders of a certain technology and to show what is needed for development. So the technology roadmaps of more mature technologies are quite different in nature compared to roadmaps of less mature technologies.

## 6.2 Characteristics of selected roadmaps

To examine the characteristics, the roadmaps were reviewed. The full review, for each roadmap separately, can be found in the appendix. In this chapter the overall characteristics are discussed in a descriptive way, sometimes considering specific roadmaps. First the purposes roadmaps can serve are discussed, than the structure is considered followed by the topics and themes covered. Then the target audience of the roadmap, the initiator of the roadmapping process and the stakeholders involved are discussed, followed by the timeframe and the scope.

### 6.2.1 Purpose

The following four main purposes for drafting a roadmap were identified in this study.

1. To set out a strategy
2. To align stakeholders' interests
3. To convince stakeholders
4. To provide information and conduct analyses

A more detailed overview of the different purposes of the studied roadmaps can be found in table 2. It should be kept in mind that the classification of purposes made is not as strict as it might appear from the table. The differences are often gradual. Furthermore the marks in table 2 should be seen more as an indication of the purpose of the roadmap. For more insight into the specific purpose of a roadmap, appendix C can be consulted.

Table 2: Purposes of examined roadmaps

| | UK CCS | US CCS | Canada CCS | IEA CCS | Poland CCS | EU Com hydr. | Australia hydr. | Hyways hydr. | US hydr. | Texas hydr. | IEA geoth. | Australia geoth. tech. | Australia geoth. dev. | Canada geoth. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Strategy** | | | | | | | | | | | | | | |
| **Outline more general strategy necessary to accelerate development** | | | | | X | X | | X | | X | | | | |
| **Outline actions necessary to accelerate development** | | | X | X | | | X | | X | | X | | X | X |
| **Identify role governments, industry and stakeholders** | | | | X | | | X | | | | X | | X | X |
| **Guidance decision-makers** | | | X | X | | X | | X | | | X | | | |
| **Examine RD&D needs, strategy to accelerate RD&D** | | X | | | | | | | | | | X | | |
| **Set out steps being taken** | X | | | | | | | | | | | | | |
| **Stakeholders** | | | | | | | | | | | | | | |
| **Bring stakeholders together, create partnerships** | | | X | | | | | | X | | | | | |
| **Create a common vision and agreed recommendations** | | | | | | X | | | X | | | | | |
| **Input for discussions** | X | | | X | X | | | | | | X | | | |
| **Convince** | | | | | | | | | | | | | | |
| **Convince, highlight the need for immediate action** | | | X | X | | | | | | | X | X | X | |
| **Convince policy makers, more support** | | | | | X | | | X | | X | | | | X |
| **Inform** | | | | | | | | | | | | | | |
| **Inform on energy sector, running projects, potential and techniques** | | X | X | | X | | | X | | | | X | | |
| **Scenario analysis: future $CO_2$ reductions, costs** | | | | | X | | X | X | | X | | | | |
| **Examine intellectual property landscape** | | | | | | | X | | | | | | | |

| | | | |
|---|---|---|---|
| UK CCS: | CCS Roadmap, supporting deployment of Carbon Capture and Storage in the UK | Hyways hydr.: | Hyways, European Hydrogen Energy Roadmap (and Action Plan) |
| US CCS: | DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap | US hydr.: | National Hydrogen Energy Roadmap (US) |
| Canada CCS: | CCSTRM Canada's $CO_2$ Capture & Storage Technology Roadmap | Texas hydr.: | Texas Hydrogen Roadmap |
| IEA CCS: | IEA Technology Roadmap, Carbon capture and storage | IEA geoth.: | IEA Technology Roadmap, Geothermal Heat and Power |
| Poland CCS: | Insuring Energy Independence, A CCS Roadmap for Poland | Austr geoth.tech.: | Australian Geothermal Industry Technology roadmap |
| EUCom hydr.: | Hydrogen and Fuel Cells: A Vision of Our Future (European Commission) | Austr geoth.dev.: | Australian Geothermal industry Development Framework |
| Austr hydr.: | Hydrogen Technology Roadmap (Australia) | Canada geoth.: | Canadian Geothermal Heat Pump Industry Technology Roadmap |

### 1. *To set out strategy*

The original purpose of roadmaps, is to set out a strategy. The main difference between the roadmaps is how detailed a strategy is set out and which types of actions are covered. In some roadmaps no actions or only a few actions are identified. In these roadmaps the strategies are outlined very general. Other roadmaps include more and more detailed actions. In some cases even a timeframe is included as well as the actors which are responsible for the actions. In this section these three types of detail are illustrated by means of the examined roadmaps.
Some of the roadmaps are more general, only few actions were mentioned or *a more general strategy was outlined*. The main goal of these roadmaps is not to set out a detailed strategy. Examples are the Texas hydrogen roadmap and the CCS roadmap for Poland. These roadmaps focus more on the outcomes of scenarios and convincing government decision-makers. Also the hydrogen vision for the European Commission and the Hyways roadmap outline a more general strategy. These roadmaps focus more on how governments can coordinate and facilitate hydrogen technology developments. Examples of actions in the hydrogen vision document are for example to develop a roadmap and other strategic plans and also to initiate a hydrogen and fuel cell technology partnership. In the Hyways documents only a few actions are mentioned. These are directed at policy support. But the actions are quite general: increasing the R&D budget, a deployment support framework, tax exemptions, creation of early markets etc. The Icelandic roadmap does not even define actions, but describes briefly and very general how to “move forward”. For most of these roadmaps the main purpose was not to set out strategy.
In other roadmaps the strategy was more elaborated, *detailed actions are outlined to accelerate the development of certain technology*. The national hydrogen energy roadmap of the US for example details for every segment of the technology the status today, vision, challenge and paths forward. Considerable attention is paid the paths forward, the actions which should be executed. However the timeframes and actors are not mentioned explicitly. Also for the Canadian CCS roadmap quite some actions are mentioned but the timeframes and actors involved are not. In some roadmaps the timeframes and actors involved are mentioned very clearly. The IEA roadmaps and the Australian hydrogen roadmap provide readers with a table in which the actions, involved actors and timeframes are given. A purpose of these roadmaps is therefore also to *identify the role of the government, industry and other stakeholders.* Some of the roadmaps serve as guidance *for decision-makers*. The clearest examples are the roadmaps of the IEA and the European hydrogen roadmaps. These roadmaps are made in order of governmental institutions, to advise them.
The roadmap for CCS in the US is a research development and deployment roadmap. It sets out a strategy but focuses almost solely on technical issues. This roadmap is very detailed on technical issues. It examines *the RD&D needs and its aim is to give direction to research* to make it as efficient as possible. The Australian Geothermal industry roadmap also focuses solely on technical issues. Again the research needs are identified. In this case also a very extensive table of actions is given, including the urgency of the actions and the stakeholders responsible.
The goal of the CCS roadmaps of the UK is to set out the *steps which are going to be taken*. Contrary to other roadmaps in this roadmap mainly actions are mentioned which will be executed by the UK government.

### 2. *To align stakeholders’ interests*

Although *bringing stakeholders together* by roadmapping processes is often seen as one of the most important goals, this goal is often not mentioned in the document itself. Only in the US hydrogen roadmap the need for partnerships between government and industry is emphasized multiple times throughout the document. Also in the Canadian CCS roadmap alliances and partnerships to advance research, development and demonstration programs and projects is seen as a goal of the process. Only these two roadmaps are marked in the table because the purpose was mentioned clearly.
Creating a *common vision and agreed recommendations* is also seen as an important purpose of the roadmapping process. This is however less often mentioned in the roadmaps. In the European Commission hydrogen vision the common vision is created by the high level group, consisting of multiple stakeholders. In the US hydrogen roadmap the need for partnerships and a common vision is emphasized multiple times.

Some roadmaps also serve as *input for discussions*. In the IEA roadmaps it is explicitly mentioned that the roadmaps are seen as input to a number of international discussions. One of the goals of the CCS roadmap for Poland is “to fuel the debate”. In the UK CCS roadmap it is literally said that “the roadmap will inform the government's dialogue with industry”. This goal is however closely related to convince certain actors to develop technologies. This holds especially for the roadmap for Poland.

*3. To convince stakeholders*

Almost all roadmaps have to aim to convince stakeholders: not only governments for more support but also companies to take action. It seems that roadmaps are not meant to convince the general public. It is never mentioned explicitly that the aim of the roadmap is to convince. It becomes clear through the tone of the document and the amount of attention paid to certain topics. In the table only the roadmaps are mentioned for which it was very clear that the purpose is to convince.
Some roadmaps seem to be made to convince *governments to put more money and effort i*nto the development of a certain technology. In the roadmap for CCS in Poland for example the need for CCS is several times stressed, also from the scenario it becomes clear that CCS should not be abandoned. This roadmap is made by BEST (Bellona Environmental CCS Team), which has a positive attitude towards CCS. Also the Texas hydrogen roadmap seems to be made to convince the government. Although three scenarios are offered (in which one of them hydrogen is hardly deployed), throughout the text it is tried to convince the Texas government that more should be done and it is shown that Texas has only few incentives compared to other states. In the Canadian geothermal industry roadmap, mainly aimed at industry, one chapter was devoted to convince the government to support industry developments.
In some roadmaps the *need for immediate action of all involved stakeholders was highlighted*. The US hydrogen roadmap for example wants to “inspire” all involved stakeholders. In the Australian geothermal development framework, the urgency is emphasized in the foreword. In the UK CCS roadmap the convincing part is more in the tone of the document. The tone is very active, it is written in the form “the UK government is going to ...”. The technical roadmaps which were examined, the roadmap of CCS in the US and geothermal energy in Australia, seemed to be most neutral. All roadmaps have however indirectly more or less an aim to convince a certain target group or the readers of the roadmap. All roadmaps are automatically positive regarding the technique the roadmap is made for. Although in some cases the message is not only aimed at governments but more broadly, the main stakeholder to convince seems to be the government.

*4. To provide information and conduct analyses*

The purpose of some roadmaps was also to execute analyses and to inform governments. In some roadmaps scenario analyses were done to examine future costs, $CO_2$ reductions and penetration rates of the technology. In the Australian hydrogen roadmap the research capabilities and strengths of Australia were assessed, the intellectual property landscape was examined. In the Canadian and Polish CCS roadmap more info was given about the energy sector, running projects and potential for CCS. In some roadmaps also the technology pathways were discussed extensively, especially in the more technical roadmaps.

## 6.2.2 Structure

It was found that all roadmaps have different structures. However, a small subset of the roadmaps has similar basic structures that will be discussed in this paragraph. Roadmaps with a different set up will not be discussed. For more detail, the analyses in the appendix can be consulted. Two sorts of structures were found. Some roadmaps first deepened into the situation now, followed by an explanation of the desirable future and the way to get there. In other documents, the largest part of the roadmap provided information and the description of the actual strategy was limited.
So, a structure which is used multiple times consists of the following elements: an introduction in which the rationale for the technology and roadmap is explained and an overview of the status of the technology today, a sketch of the desirable future, and the way to go there. The clearest examples are the roadmaps of the IEA. These roadmaps start with an introduction in which the background of the project is explained as well as the rationale for CCS and the purpose of the roadmap. This is

followed by the status of the technology today. Then the scenarios which serve as a basis of the roadmapping process are elaborated. The actions and milestones follow. The US hydrogen energy technology roadmap has the same sort of structure. However for this roadmap the situation today, the vision and paths forward are discussed for each segment of the technology separately (capture, transport and storage). In figure 1 these two types of structures are schematized.
The second type of document is characterized by large amount of information. The actual roadmap or strategy itself is only a small part of the document. This is often the last chapter or one of the first chapters of the document. One example is the roadmap for CCS in Canada. In this roadmap the energy challenge Canada is facing is elaborated, the potential for CCS is mapped, and technical issues are explained in detail. The actual roadmap follows at the end. Also the hydrogen technology roadmap for Australia has the same sort of structure. This roadmap contains a lot of technical information and analyses regarding the intellectual property landscape and economic competitiveness of hydrogen technologies in Australia. The Australian geothermal industry development framework starts with a summary of all proposed strategies. The remainder of the document consists of background information on these strategies. Also the Australian geothermal industry technology roadmap treats the issues and status of several topics first and gives an overview of the issues, solutions, goals and the timeline at the end of the document. So in all these documents the actual roadmap is separated from the large body of information as schematized in figure 1.

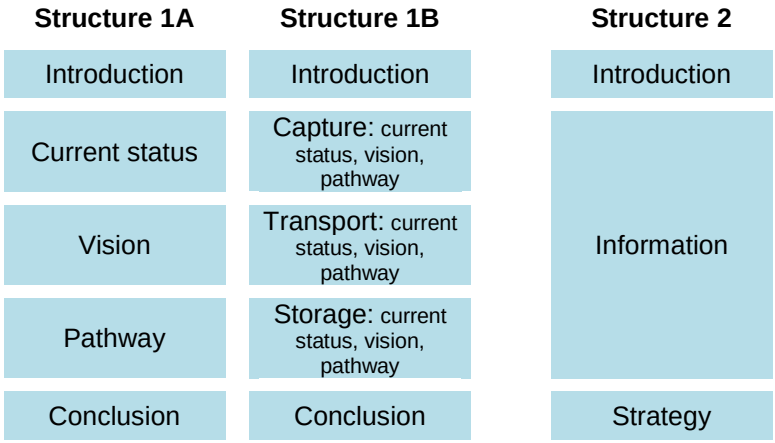



*Figure 1: schematic basic structures roadmaps*

The information and strategies are ordered in two distinct ways. In most cases information was ordered by topic. Also a distinction can be made between the different segments of the technology. This means for hydrogen technology roadmaps the distinction is made between production, delivery, storage, and use. For CCS a division can be made into capture, compression, infrastructure and storage. This is especially useful for technical roadmaps.
The structure of the UK CCS roadmap and of the Hyways roadmap for Europe was less clear. The UK roadmap was structured point wise. This made the roadmap less readable. The points were not part of an enumeration, but small independent pieces of text. Also the general structure was not very clear. The titles of the chapter were more abstract, for example “understanding the challenge: how to enable cost competitive CCS”, “realizing the vision: enabling commercial CCS”, “learning by doing, learning by research” and “tackling barriers to deployment”. In the Hyways roadmap two documents were used, a roadmap and an action plan. It could also have been one document. The documents missed a clear description of the vision, current state of technology and strategy. Furthermore the action plan actually contained only a few concrete actions. One expects different from an action plan. Also in this document abstract titles were used and the main text seemed cumbersome. Both roadmaps, Hyways and the UK CCS roadmap, missed a clear structure such as that of the IEA roadmaps.

### 6.2.3 Topic and Themes

It was difficult to determine the topics and themes discussed in the roadmaps. First of all it was difficult to name the topics and themes which were treated because there is quite some overlap between them. Also within a topic there can be some subtle differences of what is discussed exactly. It was determined that a topic was covered by a roadmap when the topic was treated in certain detail, when there was a certain focus on the topic. So if the topic was only slightly mentioned or when only a small amount of text was devoted to a certain topic, it was not considered. The table below shows the topics and themes covered by the roadmaps.

*Table 3: Topics and themes covered by roadmaps*

| Roadmap | RD&D technical | Policy and regulation | Public outreach education | Collaboration and partnerships | International collaboration | Economics and finance | Capacity building | Potential |
|---|---|---|---|---|---|---|---|---|
| UK CCS | | X | | | | | X | X |
| US CCS | X | | | | x | | | |
| Canada CCS | X | X | X | X | X | X | X | X |
| IEA CCS | X | X | X | | X | X | | |
| Poland CCS | | X | | | | X | | X |
| EUCom hydr. | | X | | | | | | |
| Australia hydr. | X | X | | | X | X | X | |
| Hyways, hydr. | x | X | | | | x | | |
| US hydr. | X | X | X | | | X | | |
| Texas hydr. | | X | | | | x | | |
| IEA geoth. | X | X | | | X | X | | X |
| Australia geoth. dev. | x | X | x | X | X | X | X | |
| Australia geoth. tech. | X | | | | | | | X |
| Canada geoth. | X | X | X | X | | | X | |

*RD&D, technical*

In almost all roadmaps RD&D is discussed. the extent to which this topic is discussed and what is discussed exactly differs. More technical roadmaps, like the Canadian geothermal industry roadmap, the US CCS roadmap, US hydrogen roadmap and the Australian geothermal industry technology roadmap, focus mainly on technical topics. In other roadmaps RD&D is discussed in less detail. In these roadmaps the topic is covered more generally next to other topics as a part of the strategy. Examples are the IEA roadmaps and the Australian geothermal industry development framework.

*Policy and regulation*

Also policy and regulations are included in almost all roadmaps. But again the extent to which this topic is discussed differs significantly. Two hydrogen roadmaps, made in order of the European Commission, are mainly focused at policy and coordination, a policy support framework. These documents are meant to support the European Commission and its member states in policy decisions. The UK CCS roadmap is about what the government is going to do, therefore mainly policy is covered. Many roadmaps seek for government support for a certain technology. Examples are the Polish CCS roadmap made by BEST, and the Texas hydrogen roadmap. Also in the geothermal roadmap for Canada one chapter is devoted to convince policymakers to support the geothermal heat pump development. In the other roadmaps policies are discussed more general deepening into the legal and regulatory frameworks and policy support frameworks needed. But in all these roadmaps policy is about how to enable the deployment and commercialization of the relevant technology and the support of the government which is needed for that.

*Public outreach and education*
In less than half of the studied roadmaps public outreach and education was treated. The extent to which the subject was treated varied significantly. In the CCS roadmap of Poland only a very small paragraph was devoted to the subject. In the Australian geothermal development framework and the CCS roadmap for Canada public outreach and education was included in the strategy but not extensively discussed. In the IEA roadmap for CCS, in both the introduction and in the strategy this topic is discussed. The US hydrogen roadmap devoted a whole chapter to the subject. The Canadian geothermal roadmap treated this subject in a slightly different way. In this roadmap the focus was on marketing and customer awareness to create a market for geothermal heat pumps. It is not always clear why in some roadmaps this subject was discussed more extensively.

*Collaboration and partnerships*
Collaboration is mainly discussed in geothermal roadmaps: sharing geo-scientific data, knowledge and experiences. The Canadian geothermal roadmap also emphasizes cooperation between different organizations. In other roadmaps the focus is more on international collaboration and on cooperation between government and industry.

*International collaboration*
International collaboration is discussed in multiple roadmaps. In the CCS roadmap of the US it is only a small paragraph. In other roadmaps it is part of the strategy. The Icelandic roadmap to enlarge international collaboration is maybe even a sort of purpose of the roadmap itself. In most cases collaboration in R&D and knowledge exchange is discussed. In the Australian geothermal roadmap however the possibility to sell technologies to other countries is also addressed.

*Economics and finance*
Economics and finance is an often addressed topic for technology roadmaps. It is considered as an important condition for technology to breakthrough or not. The focus of many roadmaps is therefore on cost developments in the future and the need for technical improvements to reduce costs. In the Hyways European hydrogen roadmap, the CCS roadmap for Poland and the IEA geothermal roadmap the future costs of technologies are examined trough scenarios. In the more technical roadmaps, like the Australian hydrogen roadmap, the hydrogen roadmap of the US, the Canadian CCS roadmap and the Icelandic hydrogen roadmap, the focus is more on costs, competitiveness and performance issues. The Australian geothermal industry development framework and the IEA CCS roadmap also deepen into the financial barriers and improvements of the financial framework. This can be done by banks or by incentives of the government. In some roadmaps also economics today are discussed.

*Potential*
Also the potential for certain technologies is shown in roadmaps. In three studied CCS roadmaps the potential for capture and storage is displayed in a map. Also for geothermal energy technology roadmaps the potential is illustrated by maps in as well the IEA roadmap and the geothermal industry roadmap of Australia.
*Capacity building*
Only few roadmaps discuss the need for workforce. The Canadian geothermal roadmap focuses on education of people so that there is enough workforce, this is an industry roadmap. Also the Australian hydrogen roadmap which is quite technical emphasizes the importance of capability building, it is mentioned as one of the activities, as part of the strategy. In the Australian industry development framework for geothermal energy it is also included in the strategy. The Canadian CCS roadmap mentions the topic workforce more briefly in the beginning of the document. In the UK CCS roadmap a whole chapter was devoted to the topic of capacity building.

*Other*
Other topics which are not mentioned in the table are existing (national) programs, the energy challenge and the energy sector of a country. Current projects were discussed in multiple roadmaps such as the Poland CCS roadmap, the Australian hydrogen roadmap and current R&D projects are discussed in the US CCS roadmap. Some roadmaps also deepen into the world energy challenge.

Also the energy sector of a country and energy security is sometimes discussed. For example the Polish CCS roadmap deepens into the current energy sector of Poland. Poland has large coal and lignite resources. Often this is linked to why CCS is needed.

### 6.2.4 Stakeholders and methodology

It was not always possible to get insight into the stakeholders involved in the roadmapping processes. In some cases the participants were listed in the appendix, but in some cases these participants were not mentioned. Furthermore the roadmapping process was not always explained, which made it difficult to assess the role of the stakeholders. Table 4 gives an overview whether stakeholders are involved and in what way, whether the participating stakeholders were mentioned in the document and the amount of stakeholders involved.

*Table 4: Stakeholder involvement and methodologies applied*

| Roadmap | Stakeholders involved | In what way involved | Stakeholders mentioned | Amount of stakeholders | Scenario analysis |
|---|---|---|---|---|---|
| **UK CCS** | yes | "development forums" | not mentioned | - | |
| **US CCS** | not clear | comment on the roadmap | not mentioned | - | |
| **Canada CCS** | yes | 3 workshops | list appendix | appr. 200 | |
| **IEA CCS** | not clear | - | not mentioned | - | X |
| **Poland CCS** | no | - | - | - | X |
| **EUCom hydr.** | semi* | high level group | list in appendix | appr. 40 | |
| **Iceland hydr.** | semi* | not clear, "contributors" | - | appr. 15 | |
| **Australia hydr.** | yes | interviewed workshop | list appendix | appr. 80 | |
| **Hyways, hydr.** | yes | input scenarios, workshop | list appendix | appr. 40 | X |
| **US hydr.** | yes | two workshops, meetings | list appendix | over 130 | |
| **Texas hydr.** | yes | workshops, discussions | list appendix | appr. 40 | X |
| **IEA geoth.** | yes | workshops | list site (not found) | - | |
| **Australia geoth. dev.** | yes | workshops, consultation | not mentioned | - | X |
| **Australia geoth. tech.** | yes | workshops, consultations, discussions | not mentioned. | - | |
| **Canada geoth.** | yes | workshops working groups | not mentioned | - | |

**In these cases the makers of the roadmap seem to be a group of stakeholders*

It becomes clear that in most roadmapping processes stakeholders are involved. They can be involved through workshops, discussions, interviews and some cases stakeholders were also invited to comment on a draft version of the roadmap. It is noticeable that for the Canadian CCS roadmap and the US hydrogen roadmap only 2 or 3 workshops are held while a lot of stakeholders are involved. This could indicate that the nature of these workshops differs significantly compared to other roadmapping workshops. Furthermore it is noticeable that still in many cases the stakeholders are not given. In most cases the set of stakeholders consisted of companies, research institutions, and industry. The proportion however differed, sometimes more institutions were involved in other cases more companies. The general public was not involved in the stakeholder workshops. Sometimes no stakeholders were involved, or it was unclear whether they were involved. In the roadmap for CCS in Poland there is no evidence or indication of the fact that stakeholders are

involved. In the roadmapping process of the UK (CCS) industry and research institutions are involved by development forums, periodically meetings. The involvement of stakeholders is however not mentioned explicitly in the roadmap, only mentioned somewhere throughout the text. Over 80 stakeholders were involved through industry days, but this is not elaborated and it is also not clear whether they contributed to the roadmap itself. In the roadmap for CCS in the US also nothing is mentioned about stakeholders. Possibly this has to do with the character of the roadmap which is very different: it is a RD&D roadmap. The involvement of stakeholders in the roadmap of Iceland and hydrogen vision of the European Commission does not become clear. The developers of the roadmap seem to be the group of stakeholders put together, respectively the “contributors” and the “high-level group”.
It is difficult to report on the methodologies applied. In most cases the process is not described. However, in some roadmaps the methodology is explained more extensively, makers of the roadmaps seem to be aware of the process and explain the process in the document. For example in the Australian hydrogen roadmap, an entire chapter was devoted to the process and the literature on roadmapping which was used for the report. It was explained that workshops, desktop research and SWOT analyses were used. For other roadmaps it only became clear that scenario analyses were done or workshops were held. In table 4 this is shown.

### 6.2.5 Target audience, Sender, Timeframe and Scope

In table 5 the target audience, sender, timeframe and scope of each examined roadmap is illustrated. The target audience was mainly deduced from the actions and information. The initiator is seen as the stakeholder who commissioned the report. In some cases this corresponds to the stakeholder which makes the roadmap. Timeframes are only mentioned when these are mentioned in the report.

The target audience of the roadmaps studied differs. A lot of roadmaps are aimed at all involved stakeholders, government, research institutions and companies. In these roadmaps actions and strategies are proposed which concern all stakeholders. It is often mentioned that the development of the technique requires effort of all stakeholders and that these stakeholders should work together. Other roadmaps seem to focus more on the government, in two different ways. The Hyways roadmap and the European Commission hydrogen vision serves as a sort of advice for governments or the European Commission itself. These roadmaps are made in order of the European Commission. The aim of the Texas hydrogen roadmap and the roadmap for CCS in Poland is more to convince, instead of help the government. The target audience of the UK government does not become fully clear. In this document it is written what the UK government is going to do. Probably it is aimed at research institutions and companies which should invest and work on CCS too. The target groups of more technical roadmaps, for CCS in the US, geothermal in Canada and Australia, are industry and research institutions which are knowledgeable about the technique.
The initiators of the roadmapping processes where mainly found to be governments, governmental institutions and research institutions. One roadmap was written by an environmental organization. The timeframe of the different roadmaps lie in the same range. The visions or the scenarios span a timeframe of a few decades, maximal to 2050 whereas the actions are more near-term spanning, maximal 5 years. The scope of the roadmaps is also similar. The roadmaps of the IEA have a global scope, two roadmaps examined have a European scope and all the other roadmaps have a national scope.

*Table 5: Target audience, sender, timeframe and scope of roadmaps*

| Roadmap, title | Target audience | Sender | Timeframe | Scope |
|---|---|---|---|---|
| **UK CCS** | Not fully clear, stakeholders | UK government | to 2030 | United Kingdom |
| **US CCS** | NETL itself, other technical stakeholders involved | National Energy Technology Laboratory, US department of Energy | to 2030 | United States |
| **Canada CCS** | All involved parties: government, Research Institutions and industry | Canadian government, CANMET | vision: 2030 | Canada |
| **IEA CCS** | All involved parties: government, Research Institutions and industry | International energy agency | actions: near term, scenario: to 2050 | global |
| **Poland CCS** | Polish government | Bellona Environmental CCS Team (BEST) | scenarios: 2011 – 2030 | Poland |
| **EUCom hydr.** | European Commission, member states | European Commission | 2003-2050 | Europe |
| **Iceland hydr.** | - | - | - | Iceland, international* |
| **Australia hydr.** | All involved parties: government, Research Institutions and industry | Australian Government, Department of Resources Energy and Tourism | actions near term and "onwards", scenarios 2008-2040 | Australia |
| **Hyways, hydr.** | Government | not clear, financed by research institutes, industry, national agencies and the European Commission | actions: near term, scenarios: to 2050 | Europe |
| **US hydr.** | All involved parties: government, Research Institutions and industry | US department of energy | vision: 2030-2040 | United States |
| **Texas hydr.** | Texas government | Houston Advanced Research Centre | actions: near term, scenarios: to 2050 | Texas |
| **IEA geoth.** | All involved parties: government, Research Institutions and industry | International energy agency | actions: 10 years, scenario: to 2050 | global |
| **Australia geoth. dev.** | All involved parties: government, Research Institutions and industry | Australian Government, Department of Resources Energy and Tourism | - | Australia |
| **Australia geoth. tech.** | Companies, institutions knowledgeable | Australian Government, Department of Resources Energy and Tourism | actions: short term 6 years | Australia |
| **Canada geoth.** | Mainly industry, also government | Canadian GeoExchange Coalition | actions: short term 3 years | Canada |

# 7 Limitations of the study

## 7.1 Collection of roadmaps

The list of roadmaps given in appendix A is not complete. This has a few reasons. The main limitations when searching for roadmaps are the search engine and the key terms used. Possibly the search engine Google gives certain results, leaving others out. A bigger limitation is probably the terms used for searching. As mentioned before these are English, meaning that only roadmaps written in English will be found. Furthermore, because one of the terms is roadmap, only documents will be found which have the word roadmap in their title or somewhere in a description.
Another limitation is also that only roadmaps which are published on Internet can be found. Roadmaps which exist in hard copies but are not published digitally were not found. Also older roadmaps are possibly not included because these roadmaps don't exist on the Internet anymore. They are possibly deleted or replaced by newer versions. Therefore only more recent roadmaps (2000 and onwards) could be found.

## 7.2 Analysis

The main limitation in analyzing the roadmaps comes from the fact that the roadmaps were studied by a person. Although reviewing the roadmaps is done in a systematic way, a lot of the results are based on interpretation. Also the insights in roadmaps differed when roadmaps were studied multiple times. Some characteristics were noticed immediately, others after studying the roadmap more than once. Although the results are supported as much as possible by quotes from the text, discussion about the results is possible to a certain extent.
Also some characteristics were more difficult to determine than others. It was difficult for example to determine the purpose of the roadmap. First of all in most cases the purpose is not mentioned clearly. Almost all roadmaps have the aim to convince the government and other stakeholders. This purpose was never mentioned explicitly. It is also difficult to determine whether bringing stakeholders together was a real purpose of the roadmap. Through workshops this is done automatically in some sort of way. Second, if the purpose is mentioned it can be discussed whether 'the roadmap does what it says do'. For example in the Icelandic roadmap it was written that the roadmap provided detailed actions. This was however not the case.
Another characteristic difficult to assess is the topics covered. First of all some topics are close to each other, or closely related. R&D for example is closely related to cost reductions and policy support for R&D, but also to international collaboration in research and development projects. Policy is closely related to economics. The cost of certain technology can be influenced by policy incentives. Second, it was not always easy to categorize topics. Roadmaps treat topics in different ways. For example, when discussing public acceptance there was a difference between roadmaps which discussed public education and roadmaps which discussed the way to make technologies more attractive to potential customers. Last also the extent to which a topic is discussed is difficult to determine.
Describing the target audience of a roadmap had the same sort of difficulties. The target audience was not always mentioned, so it had to be the deduced from the text and the actions in the roadmap. If for example the roadmap was very technical, the target audience consists of technically educated people. When only policy issues were discussed the roadmap was probably meant for policymakers. A problem when determining the target audience in this way is that the topics are automatically linked to the target audience.
The 'quality' of the roadmaps was another difficulty in reviewing them. The Texas hydrogen roadmap for example had a peculiar structure. Therefore it seemed to be less useful to study the structure of this roadmap. The Icelandic hydrogen roadmap contained text fragments which were copied from the US hydrogen roadmap, which calls into question the credibility of the roadmap.

# 8 Conclusions

In this chapter the research questions posed in the first chapter are answered. First the characteristics of roadmaps will be discussed. After discussing the characteristics, possible linkages between these characteristics are proposed. The conclusion ends with recommendations for the implementation plan for CCS in the Netherlands.

## 8.1 Characteristics

In this paragraph the sub questions concerning the characteristics are answered. This answers the first main research question: *What are the main characteristics of energy and environmental related technology roadmaps?* It should be kept in mind a selection of energy and environmental roadmaps are discussed.

- *What is in general the purpose of energy and environmental oriented roadmaps?*

Four types of purposes were found: to determine strategy, to bring stakeholders together, to convince governments and other stakeholders, to provide information and insights through analyses. To convince government and other stakeholders seems however to be the most important purpose. The technologies considered are not widely deployed yet and need support. Therefore advocates of such a technology search for support of other stakeholders, especially government. Almost all roadmaps set out a strategy. These strategies set out are probably not going to be executed. It is shown what is needed to enable a large-scale deployment, the focus is more on identifying needs or barriers. Creating a common vision and bringing stakeholders together is often seen as an important purpose of the roadmapping process. These purposes are not always mentioned in the roadmap documents.

- *What methodologies are applied in the roadmapping processes?*

Methodologies which are frequently applied in roadmaps are stakeholder workshops and scenario analyses. Scenario analyses are mainly used to examine future costs, penetration rates of technologies and $CO_2$ reduction potential. Also desktop research and SWOT analysis are used methods. Most roadmaps however not deepen into the methodologies applied.

- *What is in general the structure of energy and environmental oriented roadmaps?*

All roadmaps have different structures. The structure of approximately half of the studied roadmaps was comparable. Two sorts of structures were identified. In the first type first an introduction is given in which the rationale of the roadmap and technology is explained. Sometimes also some information about the technology and the country is given. This is followed by the status now of the technology, where to go (vision, targets and goals, scenario) and how to get there (pathways, strategy). The second type of basic structure is characterized by the large amount of information, the actual strategy is only a small part of, one chapter of the roadmap. Besides these basic structures it was also found that roadmaps were structured according to the topics or the different segments of the technology.

- *What topics and themes do energy and environmental oriented roadmaps cover?*

The technology roadmaps studied cover of broad variety of topics and themes. These are research development and deployment, technical issues, policy and regulations, public outreach and education, collaboration, economics and finance, workforce, the potential for technology in the country, the energy challenge, and existing national programs current projects. Furthermore international collaboration was discussed quite frequently. Public outreach and education was not discussed often which is noticeable. Especially for CCS this is a very important issue.

- *Who are involved in composing the roadmaps and in what way are these stakeholders involved?*

In almost all roadmaps stakeholders are involved. These are mainly involved through stakeholder workshops. In some cases they were interviewed and could comment on the roadmap. In most cases

the collection of stakeholders was a balanced composition of governments, companies, research institutions and universities. The general public seems not to be considered as a stakeholder.

- *What is the target audience of the roadmaps?*

Most roadmaps are aimed at all relevant stakeholders; some are especially aimed at the government or technically educated people. The roadmaps studied seem not to be meant for the general public.

- *Who is the "sender" of the roadmap? Who is communicating through the roadmap?*

Roadmaps are often made by or in order of governments, by governmental agencies, national research laboratory laboratories, environmental organizations and research centres. Industry and industry associations are almost never initiator of roadmaps of techniques which are not widely deployed yet. In some cases industry was however more closely involved, for example in the industry roadmaps.

- *What is the timeframe of energy and environmental oriented roadmaps?*

In general the timeframe of the roadmaps is long-term when it comes to visions and scenarios, often to 2030 or 2050. The actions and strategy often have a more near-future timeframe, up to five years. However, in some cases the timeframe of the strategy is not addressed. These strategies are more superficial.

- *What is in general the scope of energy and environmental oriented roadmaps?*

All studied energy and environmental roadmaps have a large geographical scope. Roadmaps are made for countries, states and continents. Also global roadmaps exist, but these are more to assist national governments to set up strategy, and policymaking. These are not to set out a global strategy.

- *How do the above mentioned characteristics of roadmaps relate to each other? Is it possible to make a categorization, or schematization of these roadmaps?*

The roadmap studied can be classified into five categories shown table 6. The purple category is characterized by its target audience which consists of a broad set of stakeholders. Also a broad set of topics is covered. Roadmaps in the orange category are meant for the government. The main aim is to convince the government. Roadmaps of the green category are also made for governments but these documents are more supportive. These roadmaps help in policy making. The roadmaps in the grey category are technical roadmaps. The US CCS roadmap and Australian geothermal roadmap focus more on R&D while the Canadian geothermal heat pump roadmap is an industry roadmap. The UK CCS roadmap differs from all these other roadmaps. In this roadmap a strategy is set out which is going to be executed.
From this it can be seen that the purpose and the target audience of the roadmaps are closely related. When the main purpose is to outline actions necessary for the development of a technology, the roadmap is aimed at a broad target audience. The target audience of R&D strategies are industry and research institutions. Also the main topics covered seem to be associated with the purpose and target audience.
The sender of the orange category, of which the purpose is to convince, are an environmental organization and a research centre with a positive attitude towards hydrogen. But for the other roadmaps it is mainly government. The structure, timeframe, scope, stakeholders and methodology are not very dependent on the type of roadmap. So the purpose, the target audience and the topics covered are most closely related.

*Table 6: Categorization of roadmaps. The characteristics are roughly indicated.*

| | Canada CCS | IEA CCS | Australia hydr. | US hydr. | IEA geoth. | Australia geoth. dev. |
|---|---|---|---|---|---|---|
| **Purpose** | Outline actions | Outline actions | Outline actions, analyze | Stakeholders | Outline actions | Outline actions |
| **Target audience** | Broad | Broad /government | Broad | Broad | Broad /government | Broad |
| **Sender** | Government department | IEA | Government department | Government department | IEA | Government department |
| **Topics** | Broad | Broad | Broad | Broad | Broad | Broad |

| | US CCS | Australia geoth. tech. | Canada geoth. |
|---|---|---|---|
| **Purpose** | R&D | R&D | R&D, convince |
| **Target audience** | Research | Industry | Industry /government |
| **Sender** | NETL | Government department | GeoExchange Coalition |
| **Topics** | R&D, Technical | R&D, Technical | Broad |

| | UK CCS |
|---|---|
| **Purpose** | set out strategy |
| **Target audience** | Broad |
| **Sender** | UK government |
| **Topics** | policy |

| | EUCom hydr. | Hyways hydr. |
|---|---|---|
| **Purpose** | Guide policy makers | Guide policy makers |
| **Target audience** | Government | Government |
| **Sender** | European Commission | - |
| **topics** | Policy | Policy |

| | Poland CCS | Texas hydr. |
|---|---|---|
| **Purpose** | Convince | Convince |
| **Target audience** | Government | Government |
| **Sender** | BEST | HARC |
| **Topics** | Policy, economics | Policy, economics |

## 8.2 Recommendations roadmap CATO2 project

In this paragraph the second research question is answered and recommendations are given.
*How can the insight in characteristics be applied, be translated into recommendations for making a suitable roadmap for CCS in the Netherlands?*
First some recommendations regarding the process are made followed by advice on the product. The product can have different forms. All studied products are documents, but presentations and websites are also possible. In the last part of this section the form of the product as well as issues regarding the layout will be discussed.

### 8.2.1 Recommendations regarding the process

Roadmapping processes and processes of other future studies are sometimes seen as a more important result than the product.[5] During the process stakeholders are brought together, interests are aligned and sometimes even partnerships are created. Some stakeholders might even be convinced of the technology during the workshops. The most important characteristics for the process are the methodology, stakeholders involved and the purpose.
The purpose is the most important characteristic to determine. The purpose influences which stakeholders you want to involve and which methodologies will be applied. The ultimate aim of the roadmap would be to get the actions identified executed. But if this is the aim, the roadmapping process should go further than identifying a common vision and the pathway to that vision. In this case firm agreements should be made. The roadmapping process should be an ongoing project, updating on the progress and monitoring whether the project is still on track. Major barriers should be taken away and all involved stakeholders should already be committed. For many roadmapping processes this is however too ambitious. Stakeholders are often not convinced yet about technologies which are not widely deployed.
Dependent on the purpose also the stakeholders involved are determined. In general all relevant stakeholders (industry, companies, governments, research institutions and universities) should be involved. Companies need to be involved in for example determining policy. They can identify which policy measures are needed. Governments can let companies know their expectations about futures which are desirable for society. If the roadmap is meant for the general public the involvement of citizens would also be helpful. But in this case the discussion would not be about a strategy but more about the desirability of technology and the possible reactions of the general public on the technology.
The purpose of the process also influences the methodology applied. If insight is needed on the impact of the deployment of a certain technology, or to show what the technology can achieve, scenario analyzes seem to be useful. When the aim of the roadmapping process is to identify barriers and needs and to develop an action plan, stakeholder workshops and other sorts of meetings are more useful. The scenarios give numbers on the deployment needed, but don't provide a concrete strategy.

### 8.2.2 Recommendations regarding the characteristics of the products

For many roadmapping processes a document is made on the results. The form of the document and the contents vary. The most important characteristics are the purpose, the target audience and the topics covered. These are closely related. The timeframe and the scope of the roadmaps are less variable for the techniques considered.
When making a product the most important characteristic to determine is the purpose. The purpose is closely related to the target audience. It was found that the target audience was not the general public. In some way this seems to be straightforward because the information gained in the roadmap workshops is not very interesting for the general public. Therefore this roadmap should not be directed at this target group. The information gathered during the stakeholder workshops is probably most interesting for government and companies.
The topics covered by a document are closely related to target public and the purpose of the roadmap. If the roadmap is written for research institutions and R&D departments of companies mainly technical topics are interesting. If the roadmap is aimed at companies that have to determine their strategy, future economic developments are of importance. If the aim is to convince policymakers, policy

measures as well as reasons why CCS should be developed should be emphasized. The target audience and the purpose of the roadmap should be the most important argument in deciding which topics are covered.
I would advise to make the target audience not too broad. Stakeholders with different backgrounds need different information. If a lot of information is given on different topics, separate documents can be considered. Detailed technical information for example is not very interesting for policymakers. Also a document to educate the public looks very differently from a roadmap. In this case topics like what CCS is, why CCS is needed, why CCS is safe are more important than the detailed strategy.
It is noticeable that public acceptance is not discussed very extensively in the studied roadmaps while it is a major barrier, especially for CCS in the Netherlands. Therefore public resistance and public outreach and education should be included in the roadmap for CCS in the Netherlands.
After determining the purpose, target audience and topics covered the structure of the roadmap can be made. For me a structure in which first introduction was given, and then the current status of the technology, followed by the vision and a pathway was most clear.
The timeframe of the vision and actions are in most studied roadmaps the same. But the urgency of the actions doesn't become clear. Often the actions are enumerated or shown in a table. In this way the actions seem to be equivalent. It's not clear what should happen first. A timeline is missing in the roadmaps. Although a timeline is less useful for showing detailed actions, it can give an overview and an idea of urgency .
In many roadmaps the methodology applied and the stakeholders involved are not clearly explained. Therefore it stays unclear how a certain vision was developed and by who it is supported. To give more insight into this, it is recommended that the methodology applied and which stakeholders are involved is discussed. It could also be nice to include which barriers or issues are important from a government point of view or a company point of view. The roadmap could even include opinions of different stakeholders. In many roadmaps no attention is paid to these differences, only the common vision is emphasized.

### 8.2.3 Form of the product and layout

All studied roadmaps are documents. Websites could also be used for presenting a roadmap. This will only be useful when the roadmap is updated regularly and action takes place. This is however often not the case. Furthermore the project should be a long-term project. Somebody has to keep updating the website until the end of the project. So the website will only be useful in case a lot of activity is taking place and when money is available for maintaining the website.
A document complemented by a presentation seems a more suitable product for this project. I would not use too much text unless the aim of the roadmap is to give a lot of information. Some roadmaps are complemented by summary documents or a foldout. For this project a more extensive timeline could be useful as an overview or foldout. I would make a document as well because a timeline can't include a lot of details. Furthermore a document looks more formal.

# 9 References

[1] International Panel on Climate Change, Fourth IPCC Fourth Assessment Report: Climate Change, 2007
website: http://www.ipcc.ch/publications_and_data/ar4/syr/en/spm.html

[2] International Energy Agency, Technology Roadmap: Carbon capture and storage, 2009
website: http://www.iea.org/papers/2009/CCS_Roadmap.pdf

[3] J. Koornneef, consultation on 06-06-2012

[4] Website of CATO-2 project: http://www.co2-cato.nl/, consulted on 07-06-2012

[5] R. van Est, M. Smits, G.P.J. Verbong, Techniekdynamica en reflectie op techniek, 2011

[6] W. McDowall, M. Eames. Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature. Energy Policy Journal 34(2006) 1236-1250.

[7] W. McDowall, M. Eames. Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature for UK-SHEC. UKSHEC Social Science Working Paper No. 8. 2004

[8] B. de Laat, S. McKibbin, The effectiveness of technology road mapping: Building a strategic vision. A study for the Dutch Ministry of Economic Affairs. 2003

[9] M. Amer, T.U. Daim. Application of technology roadmaps for renewable energy sector. Technological forecasting and social change Journal 77 (2010) 1355-1370.

[10] W. McDowall. Technology roadmaps for transition management: The case of hydrogen energy. Technological Forecasting & Social Change 79 (2012) 530-542

[11] R. Phaal, Public-Domain Roadmaps. Centre for technology management, University of Cambridge. 2011
website:http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/Roadmapping/public_domain_roadmaps.pdf

[12] Website UK Energy Research Centre http://ukerc.rl.ac.uk/Roadmaps/, consulted on 14-06-2012

# Appendix I: Objectives roadmaps

| Objectives - National level roadmaps |
|---|
| Energy policy formulation at national/regional level |
| To ensure energy security of the country or region |
| Identify and prioritize key technologies for future development |
| Presenting insight information to the policy and decision makers |
| Give direction to the national energy sector |
| Becoming a world leader in Renewable Energy Technologies |
| Renewable energy portfolio planning |
| Establishing future targets of obtaining energy from renewable sources |

Objective national level roadmaps, **adopted from [9]**

| Objectives - Industry level roadmaps |
|---|
| Establishing a common vision of the industry |
| Provide future direction to the industry |
| Increase collaboration within entire industry and with government |
| Propose conductive policy framework to the government |
| Identify key industry challenges and barriers from technical and commercial aspect |
| Forecast future energy markets |
| Identify industry needs to become competitive |
| Develop industry standards and future technology performance milestones |
| Formulate action plans and strategies to accelerate industry growth and rapid technology deployment |
| To ensure availability of skilled workforce required to support technology growth |
| Assess availability of supply chain infrastructure to supports future growth |
| Assess long-term financing requirement for the industry |
| Create positive perception among public related to green energy technologies. |

Objective industry level roadmaps, **adopted from [9]**

| Objectives - Organizational level roadmaps |
|---|
| Communicate vision of the company |
| Link business and technology planning |
| Provide a meaningful direction to the R&D efforts |
| Prioritize R&D projects for the company |
| Identify technologies to invest in order to remain competitive |
| Identify key technical barriers and market challenges |
| Better resource allocation |

Objective organizational level roadmaps, **adopted from [9]**

# Appendix II: List of roadmaps

In this appendix a collection of roadmaps is enumerated. These roadmaps are sorted on technology. This list of roadmaps is composed of roadmaps found using Google, and by roadmaps from existing lists [10, 11, 12]. The smart grid and nuclear technology roadmaps which are considered, are not mentioned in this appendix, but can be found in the list of roadmaps made by Phaal.[11]

*Renewable Energy (general)*

A lot of roadmaps on renewable energy could be found. The topic renewable energy is very broad and does not limit itself to a certain technology. These roadmaps sometimes also focus on energy efficiency and sustainability in a broad sense. A limited list of roadmaps is given below.

- **Road Map Renewable Energies Switzerland, An analysis with a view to harnessing existing potentials by 2050**
  Schweizerische Akademie der Technischen Wissenschaften
  2006
  http://www.satw.ch/publikationen/schriften/39_roadmap_e.pdf

- **UK renewable energy roadmap**
  Department of energy and climate change, United Kingdom
  2011
  http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2167-uk-renewable-energy-roadmap.pdf

- **USVI Energy Road Map, Charting the Course to a Clean Energy Future**
  EDIN Energy development is Island Natio ns, US Virgin Island, NREL
  2011
  http://www.edinenergy.org/pdfs/edinusvi_roadmap.pdf

- **Energy roadmap 2050**
  European climate foundation European commission
  http://www.roadmap2050.eu/attachments/files/Volume1_fullreport_PressPack.pdf

- **Sustainable Energy Roadmaps: Guiding the Global Shift to Domestic Renewables**
  World Watch Institute
  2012,
  http://www.worldwatch.org/sustainable-energy-roadmaps-report

- **Pier Renewable energy Technologies program, research development and demonstration roadmap**
  California energy commission
  2007
  http://www.energy.ca.gov/2007publications/CEC-500-2007-035/CEC-500-2007-035.PDF

- **Roadmap to renewable energy**
  Western area power administration Annual
  2011
  http://ww2.wapa.gov/sites/western/newsroom/Documents/annrep10.pdf

- **South Africa's renewable energy policy roadmaps**
  Energy research centre, university of Cape Town, For the UN Environment Programme Research Projec
  2010
  http://www.erc.uct.ac.za/Research/publications/10Edkinesetal-Renewables_roadmaps.pdf

- **Roadmap to sustainability**
  The Sarasota County, Florida
  2006
  http://www.scgov.net/sustainability/documents/SustainabilityRoadmap.pdf

- **Energy Science & Technology in China: A Roadmap to 2050**
  Yong Chen (editor), Chinese Academy of Sciences
  2009
  http://books.google.nl/books?id=XYjNUkjqUc0C&pg=PA103&lpg=PA103&dq=Hydrogen+energy+vision+and+technology+roadmap+for+China&source=bl&ots=yJL4u-JTde&sig=UqeOK0ZSR_AIXOippLZOOnPVax8&hl=nl&sa=X&ei=QuveT5KbN8mFhQfi1MSkCg&ved=0CFEQ6AEwAjgK#v=onepage&q=Hydrogen%20energy%20vision%20and%20technology%20roadmap%20for%20China&f=false

- **Roadmaps for science, energy research**
  Ministry of research science + technology, New Zealand
  2006
  http://www.msi.govt.nz/assets/EnergyResearchRoadmap.pdf

*Wind Energy*

There seems to be a small amount of roadmaps for wind energy. Searching the web, using Google as a search engine, only the following documents could be found, for as well onshore as offshore wind energy.

- **Technology Roadmap, Wind Energy**
  International Energy Agency
  2009
  http://www.iea.org/Papers/2009/wind_roadmap.pdf

- **Wind Energy Roadmap**
  Sustainable Energy Authority of Ireland
  2011
  http://www.seai.ie/Publications/SEAI_Roadmaps/Wind_Energy_Roadmap.pdf

- **Canada's wind technology roadmap**
  Natural resources Canada
  2009
  http://canmetenergy.nrcan.gc.ca/sites/canmetenergy.nrcan.gc.ca/files/pdf/fichier/81768/windtrm_summary_e.pdf

- **ORECCA European Offshore Renewable Energy Roadmap, September**
  Offshore Renewable Energy Conversion Platform Coordination Action ORECCA
  2011
  http://www.orecca.eu/c/document_library/get_file?uuid=1e696618-9425-4265-aaff-b15d72100862&groupId=10129

- **Roadmap to the deployment of offshore wind energy in the central and southern North Sea**
  Windspeed, supporting decisions project
  2011
  http://www.seanergy2020.eu/wp-content/uploads/2011/08/WINDSPEED_Roadmap_110719_final.pdf

In other documents, which are not mentioned here, the focus is on small wind turbines, or wind energy on the US Virgin Islands. Also a paper, Wind Energy Roadmap by Brendan et al. was found. In the roadmap made by TPwind, the European technology platform for wind energy, no clear vision or pathway to that vision is stated. It is more an overview of projects, outcomes of the third general assembly. So, these documents were not mentioned because the scope and form of these roadmaps are very different.

*Solar energy*

For solar energy a lot of roadmaps were found. The list below should not be considered fully complete.

- **Technology roadmap, Solar photovoltaic energy –IEA**
  2010
  http://www.iea.org/papers/2010/pv_roadmap.pdf

- **International Technology Roadmap for PV (ITRPV)**
  PVGroup, leading European crystalline silicon solar cell manufacturers
  Each year an update
  http://www.itrpv.net/status.html

- **Roadmap Zon op Nederland**
  ECN, BOM, Berenschot, EG Media, Holland Solar, OTB Solar, TNO
  2011
  http://www.ecn.nl/fileadmin/ecn/corp/Nieuws/2011/Roadmap_Zon_op_het_Zuiden.pdf

- **The US photovoltaic industry roadmap**
  **Produced by the United States photovoltaics industry**
  http://www.nrel.gov/docs/gen/fy03/30150.pdf

- **PV-Roadmap 2020**
  A study by Roland Berger Strategy Consultants and Prognos AG for the German Solar Industry Association
  2010
  http://www.sma.de/fileadmin/content/global/Investor_Relations/Documents/2010-12_16_DT_2_01_10_009_Komplett-02-Kurz_E.pdf

- **UK photovoltaic Solar Energy Road Map**
  OpTIC Technium,Glyndwr University,Centre for Solar Energy Research
  2009
  https://connect.innovateuk.org/c/document_library/get_file?uuid=b5d43db3-260c-43ff-b3a8-8ae0bbf00cb6&groupId=154351

- **The Australian Photovoltaic Industry Roadmap**
  Australian business council for sustainable energy
  2004
  http://efa.solsticetrial.com/admin/Library/David/Published%20Reports/2004/PVRoadmap.pdf

- **Technologie-Roadmap fur Photovoltaik in Osterreich**
  H. Fechner et al., im auftrag des bundesministerium fur Verkehr, Innovation und Technology
  2007
  http://www.pvaustria.at/upload/269_Roadmap%20Oesterreich%202007.pdf

- **EPIA roadmap**
  European photovoltaic industry association
  2004
  http://www.pvaustria.at/upload/270_Roadmap_EPIA_2004.pdf

- **Overview of "PV Roadmap Toward 2030" PV 2030**
  New energy and industrial technology development organization (NEDO)
  2004
  http://www.pvaustria.at/upload/273_Roadmap_Nedo_2004.pdf

- **PVNET European Roadmap for PV R&D**
  European commission directorate-general Joint Research Centre
  2004
  http://www.pvaustria.at/upload/274_Roadmap_PVNET.pdf

- **Our Solar Power Future**
  The U.S. Photovoltaic Industry Roadmap Through 2030 and beyond
  2004
  http://www.pvaustria.at/upload/275_Roadmap_US.pdf

*Biomass*

A lot of roadmaps related to biomass and bioenergy were found. The subjects of these roadmaps differ. This is because there are a lot of different types of biomass (algal, wood, crops). Also the energy end-product differs. Again this list should not be considered complete.

- **Technology Roadmap Bioenergy for Heat and Power**
  International Energy Agency, IEA
  2012
  http://www.globalbioenergy.org/uploads/media/1205_IEA_-_Technology_Roadmap_Bioenergy_for_Heat_and_Power_.pdf

- **Roadmap for Bioenergy and Biobased Products in the United States**
  Biomass Research and Development Technical Advisory Committee
  2007
  http://www1.eere.energy.gov/biomass/pdfs/obp_roadmapv2_web.pdf

- **European Bio refinery Joint Strategic Research Roadmap**
  Star-Colibri
  2011
  http://www.star-colibri.eu/files/files/roadmap-web.pdf

- **Renewable fuels roadmap and sustainable biomass feedstock supply for New York**
  New York State Energy Research and Development Authority
  2010
  http://www.nyserda.ny.gov/Publications/Research-and-Development/Biomass-Solar-Wind/~/media/Files/Publications/Renewable%20Fuels%20Roadmap/report_10_05_Renewable%20Fuels%20Roadmap.ashx

- **Roadmap for Agricultural Biomass Feedstock Supply in the United States**
  U.S. Department of Energy
  2003
  http://www.inl.gov/technicalpublications/Documents/3323197.pdf

- **A Biogas Road Map for Europe**
  European Biomass Association (AEBIOM)
  http://www.aebiom.org/wp/wp-content/uploads/file/Publications/Brochure_BiogasRoadmap_WEB.pdf

- **Study of China Biomass Energy Technology Development Roadmap**
  Energy Research Institute, National Development and Reform Commission
  2010

http://www.efchina.org/csepupfiles/report/201112445453592.4263830135715.pdf/China%20Biomass%20Energy%20Technology%20Development%20Roadmap_by%20ERI.pdf

- **National Algal Biofuels Technology Roadmap**
  U.S. Department of Energy
  2010
  http://www1.eere.energy.gov/biomass/pdfs/algal_biofuels_roadmap.pdf

- **A preliminary Roadmap for the Development of Biomass in California**
  California energy commission
  2006
  http://www.energy.ca.gov/2006publications/CEC-500-2006-095/CEC-500-2006-095-D.PDF

- **Bioenergy Roadmap**
  Seai Sustainable Energy Authority of Ireland
  http://www.seai.ie/Renewables/Bioenergy_Roadmap.pdf

- **Roadmap for Biomass Technologies in the United States**
  Houston Advanced Research Centre
  2002
  http://files.harc.edu/Sites/GulfcoastCHP/Publications/RoadmapBiomassTechnologies.pdf

- **A national Wood-to-Energy Roadmap**
  25x'25 America's Energy Future
  2010
  http://www.biomassthermal.org/resource/PDFs/consensus_recommendations_wood_to_energy_roadmap-final09_10_2010final2.pdf

- **Technology Roadmap for Plant/Crop-Based Renewable Resources 2020**
  Research Priorities for Fulfilling a vision to Enhance U.S. Economic security through renewable plant/crop-based resource use
  1999
  http://www1.eere.energy.gov/biomass/pdfs/technology_roadmap.pdf

- **Bioenergy Project Development & Biomass Supply**
  International Energy Agency
  2007
  http://www.iea.org/textbase/nppdf/free/2007/biomass.pdf

- **Global Technology Roadmap for CCS in Industry, Biomass based industrial $CO_2$ sources: biofuels production with CCS**
  Energy Research Centre of the Netherlands, Michiel Carbo
  2011
  http://cdn.globalccsinstitute.com/sites/default/files/publications/15681/global-technology-roadmap-ccs-industry-biomass-based-industrial-co2-sources-biofuels-production-ccs.pdf

- **Australian bioenergy roadmap**
  Clean Energy Council
  2008
  http://www.cleanenergycouncil.org.au/cec/resourcecentre/reports/bioenergyroadmap.html

*Hydrogen Technology*

There are many roadmaps on hydrogen technology. This list only represents a small amount of the existing roadmaps. Roadmaps not mentioned here are roadmaps from non-Western countries, roadmaps which solely focus on R&D or on a specific element of hydrogen technology. Furthermore, documents for which it is questionable whether these are roadmaps are not considered either.

- **Hydrogen and Fuel Cells: A Vision of Our Future**
  European commission
  2003
  http://ec.europa.eu/research/energy/pdf/hydrogen-report_en.pdf

- **The European Hydrogen Energy Roadmap (from collection of documents)**
  HyWays
  2008
  http://www.hyways.de/

- **UK Fuel Cell Development and Deployment Roadmap**
  UK Hydrogen and Fuel Cell Association
  2005
  http://www.ukhfca.co.uk/wp-content/uploads/2009/04/uk-fuel-cell-roadmap.pdf

- **Roadmap for H2 in the Nordic Countries**
  Part of Nordic Hydrogen Energy Foresight project
  2004
  http://www.risoe.dk/rispubl/NEI/nei-dk-4432.pdf

- **The Icelandic Hydrogen Energy Roadmap**
  Prepared for the Icelandic Ministry of industry and commerce
  2004
  https://notendur.hi.is//~dagnyarn/Losun_grodurhusalofttegunda/2004-5_Idntaeknistofnun_The_Icelandic_Hydrogen_Energy_Roadmap.pdf

- **Hydrogen Technology Roadmap**
  Wyld Group, prepared for the Australian Government
  2008
  http://ret.gov.au/Department/archive/ce/clean_energy_technologies/energy_technology_framework_and_roadmaps/hydrogen_technology_roadmap/Pages/HydrogenTechnologyRoadmap.aspx

- **Canadian Fuel Cell Commercialization Roadmap Update, Progress of Canada's Hydrogen and Fuel Cell Industry**
  Government of Canada, PriceWaterhousCoopers, Hydrogen & Fuel Cells Canada
  2008
  http://www.pwc.com/ca/en/technology-industry/fuel-cell-commercialization.jhtml

- **National Hydrogen Energy Roadmap**
  NETL, DOE - United States Department of Energy
  2002
  http://www.netl.doe.gov/technologies/hydrogen_clean_fuels/refshelf/The%20National%20Hydrogen%20Roadmap.pdf

- **Texas Hydrogen Roadmap**
  Houston Advanced Research Centre
  2009
  http://files.harc.edu/Projects/TexasHydrogen/TexasHydrogenRoadmap.pdf

- **New York State Hydrogen Energy Roadmap**
  The New York State Energy Research And Development Authority
  2005
  http://www.e2tac.org/Libraries/E2TAC_Presentations_Reports/New_York_State_Hydrogen_Energy_Roadmap.sflb.ashx

- **An update on Ohio's Fuel Cell Roadmap**
  Taratec Corporation for Ohio Department of Development
  2009
  http://thirdfrontier.com/Documents/OhioFuelCellRoadmapUpdate-033109FINAL.pdf

- **Minnesota Renewable Hydrogen Roadmap**
  Office of Energy Security, Minnesota Department of Commerce
  2010
  http://www.state.mn.us/mn/externalDocs/Commerce/Minnesota_Renewable_Hydrogen_Roadmap_Report_042710123821_MNRenewableHydrogenRoadmap.pdf

- **A national vision of America's Transition to a hydrogen economy – To 2030 and beyond**
  United States Department of Energy
  2002
  http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/vision_doc.pdf

- **Charting the Course, A program roadmap for Canada's transition to a hydrogen economy**
  Hydrogen and fuel cell committee (Government of Canada)
  2004
  http://www.randallanthony.com/files/design/h2.roadmap.pdf

*Geothermal*

There exist only a few roadmaps on geothermal energy. Four geothermal technology roadmaps were found and enumerated below.

- **Technology Roadmap, Geothermal Heat and Power**
  International Energy Agency
  2011
  http://www.iea.org/papers/2011/Geothermal_Roadmap.pdf

- **Washington Geothermal Energy Status and Roadmap**
  Washington State University, Washington state department of natural resources
  2009
  http://www.energy.wsu.edu/Documents/WashingtonGeothermalEnergyStatusAndRoadmap.pdf

- **Australian Geothermal Industry Technology Roadmap**
  Australian Government Department of Resources Energy and Tourism
  2008
  http://www.agea.org.au/dyn/media/r49/news/attachment/base/38

  **Australian Geothermal Industry Development Framework**
  2008
  Australian Government, Department of Resources, Energy and Tourism

- **Canadian Geothermal Heat Pump Industry Technology Roadmap**
  Canadian GeoExchange Coalition
  2012
  http://www.geo-exchange.ca/en/UserAttachments/article84_Roadmap_FINAL_E.pdf

*Carbon Capture and Storage*

Roadmaps on Carbon Capture and Storage are enumerated below. It also seems that roadmaps for CCS in Australia exist. There are slides, made by the Australian Government, department of resources, energy and tourism, but the real document, in case it exists, could not be found. Also a paper, "An integrated roadmap of communication activities around carbon capture and storage in Australia and beyond" written by Ashworth et al. was found. Also there were a lot of sectoral CCS roadmaps, made in order of the United Nations Industrial Development Organization (UNIDO). These

sectoral roadmaps will not be considered because the scope of the roadmap which is going to be made is broader.

- **CCS Roadmap, supporting deployment of Carbon Capture and Storage in the UK (supported by six smaller documents)**
  Department of Energy and Climate Change United Kingdom
  2012
  http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/4899-the-ccs-roadmap.pdf

- **DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap**
  DOE/NETL
  2010
  http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf

- **CCSTRM Canada's $CO_2$ Capture & Storage Technology Roadmap**
  Natural Resources Canada
  2006
  http://www.ic.gc.ca/eic/site/trm-crt.nsf/vwapj/co2capture-dioxydedecarbone_eng.pdf/$file/co2capture-dioxydedecarbone_eng.pdf

- **Technology Roadmap, Carbon capture and storage**
  IEA, International Energy Agency
  2010
  http://www.iea.org/papers/2009/CCS_Roadmap.pdf

- **Carbon Capture and Storage, A roadmap for Scotland**
  Scottish Government and Scottish Enterprise
  2010
  http://www.scotland.gov.uk/Resource/Doc/306380/0096201.pdf

- **Carbon Sequestration Leadership forum technology roadmap 2011**
  Carbon Sequestration Leadership forum
  2011
  http://www.cslforum.org/publications/documents/CSLF_Technology_Roadmap_2011.pdf

- **Our future is carbon negative, a CCS roadmap for Romania**
  BEST, Bellona Environmental CCS team
  2012
  http://cdn.globalccsinstitute.com/sites/default/files/publications/41086/fil-romania-final2-opt.pdf

- **Insuring Energy Independence, A CCS Roadmap for Poland**
  BEST, Bellona Environmental CCS team
  2011
  http://cdn.globalccsinstitute.com/sites/default/files/publications/13556/insuring-energy-independence-ccs-roadmap-poland.pdf

- **The power of choice, A CCS Roadmap for Hungary**
  BEST, Bellona Environmental CCS team
  2011
  https://docs.google.com/uc?id=0B9q_3yQMt0hoZzBMZkUwQVFzeUk&export=download

# Appendix III: Detailed analysis roadmaps

## A. Carbon Capture and Storage technology roadmaps

Title: CCS Roadmap, Supporting deployment of Carbon Capture and Storage in the UK
Published: 2012
Organization: Department of Energy and Climate Change, Office

### Purpose

In the roadmap it is written which actions the government is taking to facilitate the deployment of CCS in the UK. The roadmap sets out steps. It is the strategy of the UK government. It seems to be the strategy which they are going to implement, not a proposed strategy.
It also seems to be meant to inform industry about the measures the UK government is taking, a kind of basis for discussions between the UK government and industry. It looks like the UK government takes a leaders role.

"This roadmaps sets out how we will achieve our goal of seeing commercial deployment of CCS in the UK in the 2020s" (Page 6)
"This Roadmap sets out the strategic context for the Government's interventions to support the development and deployment of cost-competitive CCS and the steps being taken to achieve this outcome." (Page 9)
"The Roadmap will inform the Government's dialogue with industry on the actions taken to deliver cost-competitive CCS and will be reviewed accordingly." (Page 9)
"This Roadmap sets out the steps the Government will take to help facilitate the commercial deployment of CCS in the UK in the 2020s." (Page 11)
"The strategy set out in this Roadmap focuses Government action on facilitating CCS in the power sector first with the industrial sector to follow." (Page 23)

### Methodology

The methodology applied in this roadmap is not fully known to us. A vision is defined, but it does not become clear how this vision was defined and who were involved.

"Our vision is for a future with widespread deployment of cost-competitive CCS, with tens of GWs of installed capacity in the power sector and CCS on a variety of industrial applications. In such a world it might be expected that there would be clusters of power and industrial plants linked together by a pipeline network transporting CO2 to suitable clusters of storage sites offshore. The potential for such clusters already exists in several regions in the UK, including the east coast of Scotland, Yorkshire & Humber, Teesside, and around the East Irish Sea, where there are large concentrations of industry close to potential storage capacity. There are also other smaller clusters and other potential storage sites to be utilised, which would also require supporting infrastructure to be installed. The CCS Commercialisation Programme will consider projects which stimulate the development of these clusters where to do so could be beneficial to achieving the Programme objectives, is affordable and represents value for money." (Page 10)
The actions defined to achieve this vision are solely meant for the government. The actions seem to be quite detailed. It's not clear which and how much stakeholders were involved setting up these actions, or whether these actions are set up by the government alone. There is however a kind of dialog between industry, institutions and the government. There are development forums. Minutes of these forums can be found on the internet. Which stakeholders are involved exactly cannot be traced. But the roadmapping process seems to be an ongoing process.
"The Roadmap will inform the Government's dialogue with industry on the actions taken to deliver cost-competitive CCS and will be reviewed accordingly. The action plan will be reviewed through the CCS Development Forum and updated as appropriate." (Page 9)

## Structure

The structure of this roadmap is very special. It is not structured by paragraphs but more point wise. In spite of this pointwise structure, the roadmap in general isn't very clear. There are four chapters: understanding the challenge, realizing the vision, learning by doing, tackling barriers. But it is difficult to see the differences between those chapters, it seems like things are mentioned double and parts are overlapping. But this is my own interpretation. The structure of the roadmap looks as follows:

**Executive summary**

**Government's commitment to CCS**

It is mentioned that the government is committed, investments are needed now, focus on costs and risks, that they are world leading now. The vision is defined. Three key challenges are identified. Also the commitment of the Scottish government is explained separately.

**Why we need CCS**

To keep using fossil fuels; climate change; international context of climate change and agreements; why UK is suitable; advantages of CCS; multiple technologies.

**Understanding the challenge: how to enable cost-competitive CCS**

Actions are defined to achieve reduction in costs and risks.

**Realizing the vision: enabling commercial CCS**

This is about actions to create a market in which there is a clear commercial model for CCS in the UK.

**Learning by doing, learning by research**

This is about actions which relate to pilot scale deployment, demonstration projects (learning by doing)

**Tackling barriers to deployment**

Tackling barriers to deployment is about the infrastructure, storage strategies, and regulatory framework.

**Further detail**

Small chapter: it is mentioned that there are supportive documents

**Action plan**

This is a timeline in which the actions are displayed.

**Summary of actions**

## Topic and themes

Because the actions are about what the government does or is going to do, the roadmap mainly focuses on policy, interventions and regulations. These topics are often related to certain themes, like regulations and the electricity market, R&D and innovation, demonstration scale projects. For R&D however there is also an overview of future CCS research needs included. Issues related to public engagement and education are not included in this roadmap. So the focus is on policy
The supportive documents cover the following topics and themes: Innovation and R&D, Skills and supply chain, storage strategy, the regulatory framework and building networks: transport and storage infrastructure. But again these documents focus on what the government is going to do.

*Policy and regulations:*

Roadmap is aimed at what policy does support and regulation are discussed.

*Capacity building:*

This is discussed in the chapter skills and supply chain.

*Potential:*

The potential is shown in this document.

### Stakeholders

It stays unclear in which stakeholders are involved in the project and in which way they are involved. Often “industry” is mentioned as partner, important stakeholder. It is not explained which companies or sectors are covered by the term “industry”.

“As well as learning from the first competition, we have undertaken extensive engagement with interested parties through ongoing meetings and two Industry Days, which were attended by Ministers and a number of Government Departments, as well as over 80 industry organisations. As a result we have developed a Programme that will enable the market to lead on identifying the route to commercialisation by minimising the constraints that we have placed around the solutions that competition bidders can propose. “

### Public

The public consists of stakeholders which want to know about the government’s interventions in detail. The public consists of industry and research institutions and other stakeholders.

### Sender

The UK Government, Department of energy and climate change, Office of Carbon Capture and Storage, is communicating through this roadmap

### Timeframe

The timeframe is a few decades, approximately 2020, 2030.

### Scope

The scope of this roadmap is national. The roadmap focuses on Carbon Capture and Storage in the United Kingdom.

### Comments

- It’s difficult to read this roadmap.
- As well storage, transportation and capture are treated, but no real distinction is made between these three aspects of CCS.
- This roadmap is aimed at the government itself. It is stated what the government is going to do about climate change and should do about CCS.
- Sometimes the decisions made by the government are justified, for example:
- “The Government has made significant investments in CCS research, development and innovation. This investment is already showing dividends – the UK’s academic research is amongst the best in the world, international companies are choosing to collaborate with UK institutions and innovative new companies are emerging with technologies which could further reduce the cost and risk of CCS.” (Page 29)
- The roadmap itself isn’t updated but the website surrounding it reports on the progress made in meetings.
- The level of detail of this roadmap is large compared to other roadmaps. Furthermore this roadmap is supported by additional documents, which are even more detailed.

Title: DOE/NETL Carbon Dioxide Capture and Storage RD&D roadmap
Published: 2010
Organization: National Energy Technology Laboratory (NETL), US Department of Energy (DOE)

### Purpose

The purpose of this roadmap is to steer research development and demonstration projects.

"The United States can no longer afford the luxury of conventional, long-lead times for RD&D to bear results. New approaches must emphasize rapid commercialization of efficient, economic solutions that minimize $CO_2$ emissions." (Page 3)

Possibly this roadmap is also required to justify the research, the funding needed for this research or even to obtain funding. This does not become clear from the roadmap.

### Methodology

The methodology does not become clear from the document. Not really a detailed vision is defined. It's clear that the US wants to move forward, but it's more an overview document: where are we standing now and where are we going.

### Structure

**Message to stakeholders** (Why this research, how does it fit in US policy)
In the message for stakeholders the research program is explained as well as the goals for $CO_2$ emission reductions, and the reliance on coal.
**Overview** (Why CCS; What is CCS; The DOE/NETL CCS RD&D effort; goals, areas, targets, timeline; American Recovery and Reinvestment Act Impact on CCS RD&D; international collaboration; Interagency Coordination)
In the overview it is explained why CCS is needed, the technology is briefly explained, the research program executed by DOE/NETL is explained and the goals and timeline within this research program, also some things about international collaboration and the interagency coordination, collaboration with other stakeholders .
**$CO_2$ Capture and Compression** (Technical expectations and challenges, timeline, goals and targets, technology pathways (activities), other research activities)
Technologies are explained, cost and performance issues are addressed, targets and goal, pathways.
**$CO_2$ transportation and storage** ($CO_2$ transportation technical, $CO_2$ storage technical, Monitoring, Verification and Accounting technical (to satisfy regulations), Simulation and Risk assessment technical, Partnerships and Regional project, international activities
This is also a very technical chapter. In this chapter other issues except for technical issues are discussed.

The structure differs significantly from the structure of other roadmaps. Probably this is mainly because the roadmap only focuses on technical issues, on RD&D. It is noticeable that there is not really a conclusion. Possibly the first chapter, the overview contains the most important messages and the other chapters are meant as background information.

### Topic and themes

This roadmap is very technical. There are no separate chapters devoted to topics and themes such as public outreach and regulations. Only if technical issues coincidence with these topics attention these topics are mentioned or some attention is paid to them. For example when describing the demonstration projects something is told about public issues. When monitoring techniques are described it is mentioned that this is of importance for regulations. So in the part $CO_2$ transportation and storage themes such as public perception and regulations are mentioned, because these are more important issues for transportation and storage than for compression and capture.

*RD&D, technical:*
This is really a RD&D roadmap. Technologies and technological issues are explained.

*International collaboration:*
A small paragraph is devoted to this topic.

### Stakeholders

It is not clear whether a lot of stakeholders are involved in the construction of the roadmap. Although the first chapter is devoted to the stakeholders, it looks like the involvement of stakeholders in the process is very small and that the roadmap is mainly an exercise of NETL itself. This is really a report about what kind of research the NETL is going to execute, the report is made for the organization itself. Stakeholders are however invited to comment on the roadmap.

"This document provides a roadmap for NETL's CCSRD&D effort. NETL recognizes the critical need to act quickly and invites our stakeholders to fully participate. We invite your comments, suggestions, and inquiries." (Page 3)

At the end of the document there is a list of websites which can be visited for more information. These are websites of institutions which work on CCS. It's nowhere written, but possibly these institutions were involved.

### Public

The public of this roadmap is not very clear. But from the technical details it can be concluded that the public should be well educated and active in the field of CCS. The actions aren't aimed at a broad set of stakeholders, but made for the research institution itself. The public consists of NETL, itself, research institutions and maybe some companies with an interest in CCS.

### Sender

The National Energy Technology Laboratory is communicating through the roadmap. This roadmap is part of the Clean Coal Research program. The Department of Energy's, office of fossil Energy's Clean Coal Research Program is implemented by the National Energy Technology Laboratory (NETL)

### Timeframe

The timeframe is approximately a few decades, from now until approximately 2020-2030

### Scope

This roadmap focuses on the USA.

### Comments

- The structure is not very clear. It seems that the roadmap is composed of small pieces of text. In some cases some targets or timelines are shown, in others not. Possibly they have decide for each part of the roadmap separately what they wanted to say about the subject and adapted the structure.
- The focus of this roadmap is not necessarily the need to emit less $CO_2$, but more the possibility to keep using coal.
- Only efforts of NETL are mentioned. It is not a plan with actions which are aimed at a broad set of stakeholders.
- The roadmap seems to be quite detailed, complete and precise about every aspect of the technology.

Title: Insuring Energy Independence, a CCS roadmap for Poland
Published: 2011
Organization: Bellona environmental CCS team (BEST)

## Purpose

In this publication three different scenarios and the role of CCS in these scenarios are considered. These scenarios show that CCS is needed in the future to ensure "a secure economic future". Poland is a suitable country for CCS, the debate should be now because much of the power generation units require replacement and lots of coal and lignite are used. When reading the publication is seems that they want to convince the Polish government that they should develop CCS. They say that from all three scenarios constructed it can be concluded that CCS in Poland must not be abandoned. (They claim that all three scenarios cover a wide range of possible EU climate and energy policies). The goal of convincing the Polish government to develop CCS seemed to be linked to the organization which published the roadmap. BEST promotes CCS, because it can lead to significant greenhouse gas emissions. The actions are not very detailed. So the goal is not to set out a detailed, strategic plan.

"This publication has been prepared by the Bellona Foundation to fuel the debate in Poland on how to meet its emission and energy challenge". (Page 2)
"This Roadmap examines the outcomes of widely deploying CCS under three differ future energy mix trajectories. Specific figures are provided on costs, emissions and benefits. Under all three trajectories – and across a wide range of possible EU climate & energy policies – it is clear that the activities to commercialize and deploy CCS in Poland must not be abandoned." (Page 3)
"This roadmap sets out to bridge that gap by offering a realistic appraisal of CCS deployment as a means to insure against such rising $CO_2$ costs and ensure secure sustainable economic development." (Page 4)
"The roadmap presents an analysis of the current situation and outlines possible paths to take, but it does not aspire to make absolute recommendations regarding the choices that Poland needs to make to secure its future. It is, however, clear that there is one insurance policy in which Poland needs to invest in order to maintain its strong position and freedom of choice regarding its future energy supply. It must go forward with its CCS demonstration plants, and the other activities required to allow commercialization of CCS – such as continued and extended geological storage surveys, implementation of necessary policies and legal framework, public information campaigns, etc." (Page 53)

## Methodology

For this roadmap scenarios are constructed. Multiple scenarios are considered. Based on these scenario's recommendations are made, to develop CCS in Poland. It seems no stakeholders are involved.

## Structure

The structure of the report looks as follows:

**Executive summary**

**Preface and word from Jerzy Buzek**

**Background**

In the background it is explained why CCS should be deployed, the cost of $CO_2$ emissions and EU policies

**Why CCS in Poland**

Current situation: coal and lignite dependent, generating fleet very old, sensitivity price changes, future development energy sector; maintaining energy security and a competitive industry

**An Insurance policy**

In this chapter it is described that investing in CCS is a sort of insurance policy. Don't understand the analogy between these two. In this chapter the existing projects and their status are discussed, the possibilities and importance of $CO_2$ reductions in industry are emphasized, the potential for storage is explained. In this part of the report maps are included to visualize potentials and sites. Furthermore in some cases (f.e. for storage) recommendations are done. There are two small paragraphs on legal aspects and public participation.

**Paths to a Low-Carbon Polish power sector**

In this chapter scenarios and their outcomes are described. In paragraph 4.4 the utilization of biomass is covered to become even more $CO_2$ neutral.

**Safeguarding the future economy**

This is the conclusion.

**Actions**

The actions are aimed at governmental interventions. The actions are not really covering certain themes.

It is a clear structure. It becomes clear however that the focus of this report is not on the actions and strategy. Only a few actions are mentioned at the end of the report. The focus is more on the existing projects, potential and the scenarios.

**Topic and themes**

In this roadmap the small amount of actions are mentioned and these are mainly aimed at the government. The actions are not really aimed therefore at R&D directly but at policies and regulations, support. R&D measures, legal issues and public engagement and education are only considered briefly in chapter 3. The scenarios and the argument for CCS focus mainly on costs. The focus in this report is on the possibilities for CCS and the costs of the technology and the needed policies.

*Economics and finance:*
The focus is on costs and competitiveness throughout the document.

*Policy and regulations:*
The legal aspects are shortly discussed in a small text box. Also EU policies are explained. The actions defined are meant for government.

*Public outreach and education:*
Public outreach and education are shortly discussed in a small text box.

*Potential:*
The potential is shown.

**Stakeholders**

It seems that there aren't any stakeholders involved in the process of making the roadmap.

**Public**

The roadmap seems to be made for the Polish government. Actions are mainly aimed at the government. Especially the most important, explicit actions mentioned at the end of the report are meant for the government.

# ACTIONS

- Decide to make the implementation of CCS demonstration programs a political priority for Poland and appoint a Vice Minister for CCS, with the stated objective of making at least 1-2 plants operational before 2020.
- Remove one of the main obstacles for CCS by immediately transposing the EU $CO_2$ Storage Directive.
- Make available affordable capital to the private sector by reducing the risk through measures such as government warranties, grants, and loan guarantees.
- Reduce commercial uncertainties for investing in CCS facilities by either establishing an emission performance standard, providing an EUA price floor, enforcing a $CO_2$ tax, introducing a certificate programme for CCS or similar measures.
- Reduce the total cost of energy production and reduce national GHG emissions by strengthening subsidies and support programs for improving the energy efficiency in all parts of the economy
- Enforce the existing EU requisite that all new large fossil-fuelled plants are built – as a minimum – as CCS-ready facilities by putting into place the regulatory instruments needed.
- Make it feasible that new plants in all regions can be built as CCS-ready by the government taking immediate responsibility for the necessary identification of near-term storage sites and $CO_2$ transport corridors.
- Enable large scale storage of $CO_2$ by implementing necessary legislation and by fully characterising all available storage capacity in Poland, including that in the Baltic Sea, and by exploring the potential of EOR opportunities.
- Accelerate the development of carbon negative solutions and $CO_2$ storage opportunities by launching a government-funded CCS R&D programme on the scale of 100M EUR over five years, and by adopting tax incentives for private sector research.
- Launch a nationwide information campaign to introduce climate change, CCS technologies, and key actors to the general public. Begin focused public consultations with communities near likely storage sites.

Other actions, mentioned throughout the text, could be useful for a broader set of stakeholders, but still the text in general seems to be meant for the Polish government.

"To drive innovation in cost-intensive energy industries and Poland's as a leader in CCS technologies, the state needs to actively support R&D programmes aimed at CCS technologies in industry and academia. Such programmes might include a National Support System for CCS technologies, a CCS R&D Fund with on the order of 100 million EUR over five years, or appointing a Vice Minister for CCS Technologies to aid the demonstration projects, assure funding, communicate with the public, and negotiate with industry." (Page 20)
"…there are several research areas that might yield significant technological and economic benefits, including: • Low cost post-combustion solutions optimised for Polish power plant technologies • New coal pre-combustion technologies, such as underground coal gasification combined with CCS • Reduction of energy consumption in CO2 absorption processes to reduce the overall CCS energy penalty and associated additional fuel and capacity costs; • Detailed knowledge about deep underground saline formations suitable for CO2 storage. This R&D should be facilitated by participation in international exchanges and research programmes,22 both to foster fruitful collaborations and to educate more Polish engineers and scientists in CCS technologies." (Page 20)
"The Polish R&D sector should focus on the development of technologies for implementing and monitoring underground storage in deep saline formations, as developing the tools to utilize this plentiful and valuable national resource can provide Polish geological R&D institutions with a competitive advantage" (page 28)
"In general, public awareness and support for CCS will improve if the following steps are taken: • the investor begins a sincere dialogue with the local communities long before an investment decision is made, with the intention of taking their opinion into account when deciding on which site to put forward in permit applications • the government, environmental NGOs and independent experts are involved in the dialogue • information material in Polish is provided to citizens living in proximity of the capture, transport and storage area • CCS is put

into the context of the climate and energy challenge • local communities should profit from storage, e.g. as the CCS amendments to the Geological and Mining Law suggest to provide the municipality with a special tax of app. 0.50 EUR per tonne of CO2 stored." (Page 28)

**Sender**

The organization which made and published the roadmap is the Bellona environmental CCS team (BEST).

**Timeframe**

The timeframe used in the scenarios of this roadmap spans a few decades: from 2011 to 2030.

**Scope**

The scope of the roadmap is national.

**Comments**

- The drivers seem to be different compared to other roadmaps. For this roadmap the drivers are rising $CO_2$ costs and securing sustainable economic development in Poland. In other roadmaps the focus is more on mitigating climate change, reducing $CO_2$ emissions. Less attention is paid to economic development although CCS is sometimes seen as a relatively low cost option for reducing $CO_2$ emissions.

| | |
|---|---|
| Title: | IEA technology roadmap, Carbon Capture and Sequestration |
| Published: | 2009 |
| Organization: | International Energy Agency |

### Purpose

The purpose of the IEA roadmap is to aid policy makers, industry and other stakeholders. The document provides information about which actions are needed to develop CCS. Furthermore one of the purposes also seems to convince national governments of CCS. This becomes apparent from the foreword, but also words like “the urgent need”.

“There is a growing awareness of the urgent need to turn political statements and analytical work into concrete action. To spark this movement, at the request of the G8, the International Energy Agency (IEA) is developing a series of roadmaps for some of the most important technologies.” (page 1)
“The IEA has shared the roadmaps as input to a number of international for a, including the United Nations Framework Convention on Climate Change Technology Mechanism discussions, the Major Economies Forum on Energy & Climate and Clean Energy Ministerial. The roadmaps were featured in the recent **Energy Technology Perspectives** publication. Based on its experience, and to respond to requests for guidance, the IEA has developed a Guide to developing and implementing Energy Technology Roadmaps that can be used by government and corporate stakeholders to use roadmaps as a strategic planning tool.” (Site IEA)
“This roadmap was developed to provide a vision for addressing the above challenges. “ (page 7)
“This roadmap has responded to the G8 and other governments leaders’ requests for more detailed analysis regarding the growth pathway for CCS, a key GHG mitigation strategy.” (Site IEA)
“This roadmap details actions and milestones to aid policy makers, industry and public stakeholders in their efforts to successfully use CCS as a GHG mitigation technology. “ (page 42)

### Methodology

The vision is created by the BLUE map scenario. From this scenario the targets and milestones are determined. The targets and milestones were developed by a group of experts as can be read in the quote below.

“This roadmap outlines a set of quantitative measures and qualitative actions that define one global pathway for CCS deployment to 2050. This roadmap starts with the IEA Energy Technology Perspectives (ETP) BLUE Map scenario, which describes how energy technologies may be transformed by 2050 to achieve the global goal of reducing annual CO2 emissions to half that of 2005 levels.” (page 13)
“The process started with a review and assessment of existing efforts by IEA member countries; international collaborative efforts like the Carbon Sequestration Leadership Forum (CSLF), the Global Carbon Capture and Storage Institute (GCCSI), the IEA Implementing Agreements Greenhouse Gas R&D Programme (IEA GHG) and Clean Coal Centre, and the IEA Working Party on Fossil Fuels; and efforts by other government, industrial and non-governmental organizations. Existing recommendations, such as those from a series of IEA/CSLF workshops in 2007 to 2008, were used as a starting point.[2] The process then engaged groups of experts from a broad variety of disciplines with the objective to develop a draft roadmap that focuses on the technical, legal, policy, financial and public engagement issues need to be addressed to move CCS from today’s early demonstration projects to full-scale commercialization.” (page 7)

### Structure

The structure of the roadmap is clear. First the status today is discussed, than the scenario, which serves as a vision, as “where to go”. Then the path towards this vision is explained.

**Foreword**

**Key findings**

This chapter serves as a kind of summary

**Introduction**

In the introduction the background of the roadmapping project, the rationale for CCS and the purpose of the roadmap are explained

**CCS status today**

Five themes: Technology development and demonstration, Integration and scale-up of technologies, financing projects, legal and regulatory frameworks, public engagement and education

**CCS Deployment Requirements in the IEA BLUE Map Scenario**

In this chapter the BLUE Map Scenario, which serves as a vision in this roadmap, is explained and the implications of this roadmap are explained. Also the CCS costs and investment costs are identified as well is the amount of CCS project needed.

**Technology Development: Actions of Milestones**

**Additional Recommendations: Actions and Milestones**

In the Additional recommendations, actions and milestones are given for financing, legal and regulatory issues, public education and engagement and international

**Conclusion and near term actions**

### Topic and themes

A broad set of topic and themes are covered:

- Technology development ($CO_2$ capture, transport and storage)
- Financing
- Legal and regulatory issues
- Public education and engagement
- International collaboration

All these issues are treated quite extensively. For all these themes, actions and milestones are mentioned.

### Stakeholders

A few times it is mentioned that the roadmap is made in consultation with stakeholders. It's not written who these stakeholders are exactly. There is also no list of stakeholders in the appendix.

"This report is the result of a collaborative effort between the International Energy Agency (IEA), its member countries, and various consultants and experts worldwide." (Disclaimer)

"The process started with a review and assessment of existing efforts by IEA member countries; international collaborative efforts like the Carbon Sequestration Leadership Forum (CSLF), the Global Carbon Capture and Storage Institute (GCCSI), the IEA Implementing Agreements Greenhouse Gas R&D Programme (IEA GHG) and Clean Coal Centre, and the IEA Working Party on Fossil Fuels; and efforts by other government, industrial and non-governmental organisations. Existing recommendations, such as those from a series of IEA/CSLF workshops in 2007 to 2008, were used as a starting point. The process then engaged groups of experts from a broad variety of disciplines with the objective to develop a draft roadmap that focuses on the technical, legal, policy, financial and public engagement issues need to be addressed to move CCS from today's early demonstration projects to full-scale commercialisation." (page 7)

### Public

The public of the roadmap consists of everyone who is involved in CCS deployment, such as governments, industry and research institutions. This is mentioned explicitly and it can be deduced from the actions in the roadmap. The actions in the roadmap are meant for a broad set of stakeholders: ministries, universities, industry, local governments, NGO's, Multilateral Development Agencies, pipeline transport regulators. The roadmap is not really aimed at civilians or people who want to know something more about CCS.

### Sender

The sender of the roadmap is the International Energy Agency (IEA).

"The IEA is an autonomous body, which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme." (About the IEA)

"The OECD is a unique forum where the governments of 30 countries work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The OE CD provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies." (About the IEA)

### Timeframe

The timeframe of this roadmap is a few decades, to 2050.

**Scope**

The scope of the roadmap is very broad. It is not aimed at particular countries, but as a more general guideline what the world should do as a whole and how international and national policies can contribute to this. In the document the need for national policies is however stressed.

**Comments**

- In the roadmap it is emphasized a few times that the document should be updated, that the document should be a living document. It seems like, however, that the roadmap is not regularly updated. The latest version is published in 2009.

"This resulting roadmap is designed to be a living document and will be updated regularly to address new developments" (page 7)
"The CCS Roadmap is meant to be a process,one that evolves to take into account new developments from demonstration projects, policies and international collaborative efforts. The roadmap has been designed with milestones that the international community can use to ensure that CCS development efforts are on track to achieve the GHG emissions reductions that are required by 2050. As such, the IEA, together with government, industry and NGO stakeholders, as well as the CSLF and the GCCSI, will report regularly on the progress that has been achieved toward this roadmap's vision. For more information about the CCS Roadmap inputs and implementation, including additional analysis that informed the conclusions in this document, visit www.iea.org/roadmaps/index.asp."

- The actions mentioned in this document are sometimes in between goals and actions. Maybe this has to do with the fact that the roadmap has a global scope. Therefore the actions are more general in nature.

Title: Canada's $CO_2$ Capture & Storage Technology Roadmap
Published: 2006
Organization: Canmet Energy Technology Center, National Resources Canada

## Purpose

In this roadmap a lot of purposes are mentioned. In the quotes below some of these purposes can be found. My own interpretation is that this document is mainly informative. The roadmap for Canada is a very extensive report. The largest part is about the energy landscape, the potential for CCS in Canada and the state of the technology. The last part of the report, in which objectives and actions are defined, should help industry and government to make decisions about what to do. Another goal of this roadmap can be to bring stakeholders together. This can be deduced from the methodology and stakeholders involved in the process.

"Recognition of the role CCS can play in moving Canada closer to a low-emissions energy future has led to the writing of this **guidance document** on CCS technology in …" (page vii)
"This roadmap is a **snapshot of key information** government policymakers and industry decision makers need to know regarding Canadian opportunities in developing an deploying CCS infrastructure and systems," (page vii)
"To **bring action** to the roadmap and fulfill the vision, a number of critical objective are identified along with implementation champions whose responsibility will be to bring action to these objectives." (page ix)
"The message emerging from the roadmap initiative is the need for action today, to enable the vision of …" (page 78)
"mission to identify the **technology strategies** and the process and integration system pathways needed to allow $CO_2$ to be captured and stored in Canada. As such, both organizations engaged in developing a technology roadmap to act as a **guidance piece on potential technology pathways** for the near and longer-term timeframes"
"The ultimate goals of the CCSTRM process include:

- **Accelerating** the development of cost-effective $CO_2$ capture, transportation and storage technologies
- Building on the **intellectual foundation** that already exists in Canada to enable the development of a home-grown, world class CCS industry
- **Forging alliances and partnerships** to advance research, development and demonstration programs and projects"

This is complemented with:

- " Determine whether the emerging global and national energy context necessitates a role for CCS
- Identify the opportunities for CCS technologies
- Define the current state of applicable CCS technologies in the Canadian contexts
- Provide a summary of specific technology needs for Canada and a pathway for developing term
- Identify the critical next steps and the champions to facilitate the vision in this roadmap" (page 14)

"This roadmap is an **information source** and a **planning tool** to help industry, government and other stakeholders to evaluate promising new CCS technologies, and to serve as a guide for R&D and demonstration **decisions** being made today" (page 16)

Other purposes of the roadmap are to set out a strategy, help decision makers. Forging alliances and partnerships is also mentioned as one of the goals.

## Methodology

"The process consisted of four phases between 2003 and 2005, which included first a situation analysis, second the identification of technology pathways and research and development (R&D) strategies, third the setting of priority opportunities for R&D, demonstration and deployment, and finally the writing of the CCSTRM" (page 14)

So in the first phase information was gathered about the potential for CCS in Canada: where $CO_2$ is emitted and where it potentially can be stored, situation now. A vision was created through stakeholder workshops. Also the technology needs of industry and need for information of the government, the actions needed, and the potential for pilots and demonstration projects were discussed through workshops. What are called objectives in the report are more themes on which action must occur. The vision stated is not very clear. It is repeated a few times that *"Technology for today's energy economy providing the basis for transformative change tomorrow."* This vision is quite

abstract and vague. At the end however 'where they are going' is explained more clearly. In this chapter the impacts of achieving objectives are described.

**Appendix B: Roadmap Process**

This CCSTRM is the result of a consultative process held mostly from 2003 to 2005, during which four phases were undertaken.

Phase 1: Situation Analysis

A body of background information on the major emitting industry sectors and on geological storage capacity was gathered and compiled for discussion at the first CCSTRM workshop.

Phase 2: Technology Pathways and R&D Strategies

A vision of a de-carbonised energy economy in Canada was developed through two workshops which were used to bring together a broad range of stakeholders, including industry, government, the research community and non-government organizations (NGOs), on the subject. Participants also included international experts on CCS who gave their input into the Canadian process.

The first workshop (September 18 to 19, 2003) was designed to identify $CO_2$ capture technologies and systems that could be broadly applicable to three key Canadian industry segments: upstream oil & gas, downstream oil & gas and other industry sectors (which included thermal electricity). The second workshop (March 29, 2004) was intended to stimulate discussion on industry's technology needs, and government's information needs, related to $CO_2$ capture, transportation and storage.

Phase 3: Priority Opportunities for R&D and Deployment

This phase was undertaken to identify opportunities to apply the top priority technologies in pilot, demonstration and commercial-scale projects. The process included the distribution of a draft CCSTRM, with suggested CCS technology applications, to initiate further discussion during a third and final workshop. Participants at the third workshop (February 28, 2005) discussed and commented on the draft CCSTRM. Sessions were held on specific roadmap topics including "putting action to the roadmap", and, "recommended next steps".

Phase 4: Final Draft of CCSTRM Report

Stakeholder input both during and after the 3rd workshop was reviewed and considered for inclusion in the final CCSTRM. A draft roadmap was written for review by the Roadmap Advisory Committee, which worked to provide commentary on a final roadmap that reflects the appropriate tone and content for such a document. Members of the Roadmap Advisory Committee will continue to help in setting up a process for the implementation of the roadmap, to help achieve the objectives identified in Section 5 of the document.

While the contributors to this document have provided their respective information and perspectives in good faith, and with a view to developing a comprehensive technology roadmap for $CO_2$ capture and storage, the contributors make no representation or warranty as to the accuracy and completeness of such information or necessarily endorse the collective views or perspectives provided for herein.

## Structure

A large part of the roadmap is devoted to technical and practical information for CCS in Canada. This corresponds to one of the goals which is to give information and sort things out ("Determine whether the emerging global and national energy context necessitates a role for CCS; Identify the opportunities for CCS technologies; Define the current state of applicable CCS technologies in the Canadian contexts; provide a summary of specific technology needs for Canada and a pathway for developing term"). In the end of the report the actual roadmap is given. ("Identify the critical next steps and the champions to facilitate the vision in this roadmap")

**Executive summary**

**1. An Opportunity for Canada – Carbon Dioxide Capture and Storage (4 pages)**

This is the introduction. In this part of the roadmap, which consist only of a few pages it is explained what CCS is; why CCS is important; the vision and the goals of the roadmap exercise are explained and the contents of the roadmap are mentioned.

**2. The Challenges – An Issues Scan (13 pages)**

This part is an "in-depth explanation of why CCS is necessary". An explanation is given of the world energy scene and that of Canada. The challenges the energy system is facing are mentioned: the environmental concerns, alternative energy sources, resource recovery, and effective policy. This last challenge is explained for CCS.

**3. The Opportunities – Low-Emissions Fossil Fuels (10 pages)**

In this part of the document the role of CCS in a global and national setting is explained. The global storage potential and sources are mapped and the opportunities for Canada are mentioned.

**4. Technology pathways (22 pages)**

In this part of the document, technical possibilities for each part of CCS and the integrated system are given. It's about technology pathways and R&D. So much is told about different technologies: the features, advantages, disadvantages, sometime costs, R&D needs subdivide in storage capture and transport technologies.

**5. The way forward (15 pages)**

In this part the objectives are defined. Achieving these objectives is needed to realize the vision. For each objective, actions are given. The objectives cover a relatively broad set of themes: Policy and Regulatory Frameworks; Public outreach and education; Technology watch and international collaboration; Science and Technology R&D; Demonstrations; National Stakeholder Coordination. It is also mentioned who should execute these actions, what the outputs and desired outcomes are. This part is concluded with the people who should initiate the plan, and the impacts when the objectives are achieved.

### Topic and themes

The topics and themes covered are very broad when considering the last chapter in this document.

- Policy and Regulatory Frameworks
- Public outreach and education
- Technology watch and international collaboration
- Science and Technology R&D
- Demonstrations
- National Stakeholder Coordination

Public outreach and education, collaboration and partnerships and international collaboration are part of the strategy. Also the potential for CCS in Canada is shown. When explaining technology pathways also costs are considered. Technical needs are mapped. Policy and regulatory frameworks and national stakeholder coordination are also part of the strategy.

### Stakeholders

It is clear that stakeholders are involved in composing this roadmap. In the appendix a list of stakeholders who were participation in the workshop are mentioned. Also the stakeholders who financed the project, indivual efforts and the roadmap advisory committee are mentioned in the beginning of the document. It seems to be a balanced composition of stakholders, including all types of important stakeholders.

### Public

The public of this roadmap is government policymakers, industry decision makers, and other stakeholders.

"This roadmap is a snapshot of key information **government policymakers and industry decision makers** need to know regarding Canadian opportunities in developing an deploying CCS infrastructure and systems," (page vii)
" This roadmap is an information source and a planning tool to help **industry, government and other stakeholders** to evaluate promising new CCS technologies, and to serve as a guide for R&D and demonstration decisions being made today. (page 16)

### Sender

The sender of the roadmap the Canadian government, but the roadmap is 'mainly' made by the CANMET Energy Technology Centre.

"Canada's federal government, provincial governments and industry have a strong interest in this technology area. Under the leadership of the federal Climate Change Innovation and Technology Program, in 2001, the Canadian stakeholders began to develop a $CO_2$ capture and storage strategy for Canada as part of a larger low emissions energy agenda. It was decided that a technology roadmap would be written on $CO_2$ capture and storage strategy for publication and distribution of interested parties. Industry Canada and Natural Resources Canada (NRCan), through the CANMET Energy Technology Centre in Ottawa (CETC-O) provided initial support and facilitation for a process that has led to the creation of Canada's Carbon Dioxide Capture and Storage Technology Roadmap (CCSTRM)" (page 14)

### Timeframe

Although the timeframe is not always clear when actions are defined (it's only very explicitly mentioned in the results when the objectives are fulfilled) the timeframe is a few decades (2030)

### Scope

This roadmap has a national scope. (International issues are addressed more briefly)

**Comments**

- This roadmap is very extensive

## B. Hydrogen technology roadmaps

Title: Hydrogen Technology Roadmap
Published: 2008
Organization: Prepared for the Australian Government Department of Resources, Energy and Tourism by Wyld Group Pty Ltd in conjunction with Mclennan Magasanik Associates (MMA) and bwiseIP

### Purpose

The objectives of the roadmap are stated in the document. The first goal of the process is to assess hydrogen research capabilities and strengths. The second goal is to identify actions which Australia can take and the role of the government, industry and researchers.

"The objectives of the hydrogen roadmapping process were to assess Australia's hydrogen research capabilities and strengths and to identify what actions Australia could take to prepare for the possible emergence of a hydrogen economy."
"To this end, the roadmap identifies, among other outputs, the suggested role of Australian governments, industry and researchers in enabling and facilitating the development of a hydrogen economy in Australia. It recommends a range of strategies and initiatives suggests responsibilities for implementation and proposes a time frame for implementation."
"This hydrogen roadmapping project had two overarching objectives:

- To assess in what areas of hydrogen technology Australia currently has research capabilities and strengths, compared to research overseas; and
- To identify what actions Australia should take to prepare for the possible emergence of a hydrogen economy, and the economic case for each of these options."

The roadmap provides information for stakeholders, about current status and activities, the role of Australia in R&D, future expectations. Two analyses are executed.

"To gain an understanding of Australia's relative position globally an analysis has been undertaken of the intellectual property (IP) landscape for hydrogen-related technologies."
"To gain an understanding of their economic competitiveness and market potential, a study was made of the costs in Australia of production and delivery of hydrogen as a fuel and of electricity from stationary fuel cell systems as a distributed generation product."

The last chapter is actually the roadmap. In this chapter it is identified which actions should be taken, and who should take these actions.
Last, many stakeholders are brought together. This is not mentioned explicitly as a goal, but is an effect of this process.

### Methodology

The makers of the roadmap are well informed of the methodologies available. The process is however not explained in detail. It is mainly explained how the information was gathered.

"Roadmapping is traditionally a technology planning process to help identify, select, and develop technology alternatives to satisfy a set of product needs. It starts with needs, not solutions. The main benefit of technology roadmapping is that it provides the information that is necessary to help make better technology investment decisions. In developing this Australian roadmap for hydrogen and fuel cells, this **needs-driven approach** has been kept foremost. That is, the development of this roadmap **did not start with the endpoint of a desirable hydrogen future** already defined — in contrast to many similar planning processes elsewhere. It is important to note that the set of needs, as discussed in Section 2.3, can also be satisfied by technologies that do not involve hydrogen and fuel cells. To develop a credible and defensible roadmap for use by Australian governments and researchers, together with suppliers and customers in the hydrogen and fuel cell value chains, Wyld Group, in conjunction with its partners McLennan Magasanik Associates (MMA) and b*wise*IP Pty Ltd have: Undertaken bottom-up **data gathering through extensive and direct consultation with stakeholders** by:

- Preparing a **discussion paper** for targeted use with key stakeholders to focus the consultation process and responses;

- Carrying out one-on-one **interviews** with stakeholders from industry, research and government — nationally and internationally — about opportunities and constraints facing hydrogen and fuel cell technologies.
- Conducting **workshops** in Melbourne, Perth and Brisbane with cross-sectional representation to enable sharing of views and cross-fertilisation of ideas;
- Attending the IEA/IPHE Workshop on Building the Hydrogen Economy: Enabling Infrastructure Development in Shanghai from 22–24 October 2007; and
- Holding meetings in New Zealand to discuss the development and progress of, and outcomes from, the current New Zealand hydrogen technology roadmapping project.

Undertaken **desktop research** in order to:

- Collect and review relevant national and international publications and the outputs of similar roadmapping projects overseas;
- Model costs in Australia of production of hydrogen and of stationary power generation using fuel cells to provide a forecast of uptake of each in competitive markets here; and
- Identify, at a high level, the international and national intellectual property (IP) landscape for hydrogen and fuel cells.

Completed a draft roadmap document, and tested it and the analyses behind it through further key stakeholder consultation, including one additional stakeholder workshop in Sydney. It is emphasised that development of any technology roadmap is done with the best data available at the time to optimise the factors that affect a technology's development. The practitioners in the field, however, will still have to deal with day-to-day successes and setbacks to reach their and the roadmap's goals."

### Structure

The structure of the roadmap looks as follows:

**Executive summary**

**1. Introduction**

Purpose of the roadmapping process; why initiated, background, methodology applied, distinction hydrogen and fuel cells

**2. Hydrogen and Fuel Cells – Global activities**

In this chapter the status of hydrogen and fuel cells today is summarized. The production, use, costs and the competitive position related to other energy carriers is elaborated. Different types of fuel cells are described as well as the different applications of fuel cells and the costs. Also the possibility of other technologies becoming dominant is discussed. So,

"Section 2.3 makes it clear that governments and industry sectors have options available to them, to deliver low GHG emission energy services to consumers. The discussion in Sections 2.1 and 2.2 also makes it clear that hydrogen as an energy carrier and fuel cells as an energy conversion device are undergoing significant consideration and development as one of these options."

In the last part it is described which (research) programs already exist for the deployment of hydrogen.

**3. Hydrogen and Fuel Cells – Australia**

In this chapter it is described which companies in Australia are active in the area of hydrogen and fuel cells. Which innovation activities are taking place at the moment in Australia (R&D and demonstration projects). An analysis is executed: the intellectual property landscape, in which Australia is compared to other countries.

"To gain an understanding of Australia's relative position globally an analysis has been undertaken of the intellectual property (IP) landscape for hydrogen-related technologies. IP landscaping is a broad term that covers, as it suggests, any review of the topography or position relative to competitors (countries and companies) afforded by IP. Patents, as a major component of intellectual property and a primary source of technological information, offer a unique resource for analysing the process of technological change and measuring the knowledge base and competitive position of a given industry or country."

Also another analysis is executed:

"To gain an understanding of their economic competitiveness and market potential, a study was made of the costs in Australia of production and delivery of hydrogen as a fuel and of electricity from stationary fuel cell systems as a distributed generation product."

**4. Strategic analysis**

Drivers of change on Australia's energy system.

The need for hydrogen and fuel cells in Australia.
Key barriers and challenges for hydrogen and fuel cells.
Australia as 'taker' or 'maker'
SWOT analysis (Strengths, Weaknesses, Opportunities, Threats)
**5. Conclusions**
**6. A hydrogen and fuel cells roadmap for Australia**
Vision, Recommended strategies, Options for key activities, Roadmap implementation

Appendix A – BwiseIP's Australian Market-Based IP listing (Analysis 1)
Appendix B – MMA's cost and market potential analysis (Analysis 2)
Appendix C – Stakeholders consulted
Appendix D – Hydrogen data and equivalencies

This roadmap is a very extensive report. Chapter 6 is the roadmap. The other chapters are the input for the roadmap. Much analysis has been done, much information is gathered. Therefore it is a large document.

### Topic and themes

A broad set of topics and themes are covered. The actions mentioned in the document cover several topics and themes.

- Market support mechanisms (policy)
- Options analysis modeling (research, international collaboration)
- Active in international forums (international collaboration)
- Education and outreach
- Coordinated sector representation (set up institution, policy)
- Regulations, codes and standards (regulations)
- Viable near term applications (promote, policy)
- Large scale demonstrations (policy, R&D)
- World-scale, collaborative R&D projects (R&D)
- Capacity can capability building (

### Stakeholders

In appendix C a list of people who contributed to the roadmap is given. Most stakeholders seem to be from government, institutions, universities and research institutions. A smaller part of the stakeholders are companies.

### Public

The public of this roadmap is quite broad. It's not only aimed at government but also at researchers and industry. This can be concluded from several parts of the text.
"To this end, the roadmap identifies, among other outputs, the suggested role of Australian governments, industry and researchers in enabling and facilitating the development of a hydrogen economy in Australia." (page i)
"Drawing from the key conclusions in the previous Section, Australian governments, industry, researchers and the broader community should collaborate and co-invest: …" (page 61)
"Implementation of this roadmap would require a long term commitment from the public, private and research sectors." (page 66)

Also the actions, displayed in a table in chapter six, are aimed at industry, government and research institutions.

### Sender

The roadmap is made in order of the Australian Government Department of Resources, Energy and Tourism, which is therefore considered as the sender.

### Timeframe

The (concrete) actions are mostly near-term. The longer term actions should be executed from 2008 onwards.
In the analysis of the market potential for hydrogen in transport and electricity generation, in appendix B, a longer timeframe up to 2040 is used in the models. Also the cost calculations in the report have a timeframe of a few decades, until 2040.

**Scope**

This roadmap has a national scope.

**Comments**

- A clear distinction is made between fuel cells and hydrogen.

"it is important to treat hydrogen separately from fuel cells. Discussions of the hydrogen economy often do not adequately distinguish between these two." (page i)

Title: Hydrogen Energy and Fuel Cells: A vision of our future
Published: 2003
Organization: European Commission, high level group

## Purpose

The purpose of this document is to inform and advice the European Commission. The high level group created a vision, showing the potential for hydrogen technologies in Europe. They also formulated some actions and recommendations. A second purpose can be to bring stakeholders together. The high-level group is composed of different types of stakeholders, which had to formulate a broadly supported vision.

"The group was invited to formulate a **collective vision** on the contribution that hydrogen and fuel cells could make to the realisation of sustainable energy systems in future." (page 5)
"The terms of reference for the group requested the preparation of a vision report **outlining the research, deployment and non-technical actions that would be necessary** to move from today's fossil-based energy economy to a future sustainable hydrogen-oriented economy with fuel cell energy converters." (page 5)
"The report aims to capture a **collective vision** and agreed **recommendations**." (page 5)
"With these factors in mind, we established the High Level Group for Hydrogen and Fuel Cell Technologies in October 2002, and asked its members to come forward in six months with a **collective vision** of how these technologies could help meet Europe's aspirations for sustainable energy systems. This report is the result and, we believe, a first milestone." (page 6)
"In this document, the High Level Group highlights the potential of hydrogen-based energy systems globally, and for Europe in particular, in the context of a broad energy and environment strategy. It then proposes research structures and actions necessary for their development and market deployment." (page 9)

## Methodology

"The High Level Group for Hydrogen and Fuel Cells Technologies was initiated in October 2002 by the Vice President of the European Commission, Loyola de Palacio, Commissioner for Energy and Transport, and Mr Philippe Busquin, Commissioner for Research. The group was invited to formulate a collective vision on the contribution that hydrogen and fuel cells could make to the realisation of sustainable energy systems in future."
The high-level group consists of stakeholders: people from companies and from governments. So by a group of stakeholders a kind of vision was developed. The vision is not explicitly mentioned but part of the second chapter, why Europe should develop and deploy fuel cells (quotes below). Probably the actions also followed from the high level group meetings.

"Fuel cells will be used in a wide range of products, ranging from very small fuel cells in portable devices such as mobile phones and laptops, through mobile applications like cars, delivery vehicles, buses and ships, to heat and power generators in stationary applications in the domestic and industrial sector. Future energy systems will also include improved conventional energy converters running on hydrogen (e.g. internal combustion engines, Stirling engines, and turbines) as well as other energy carriers (e.g. direct heat and electricity from renewable energy, and bio-fuels for transport).
" In brief, hydrogen and electricity together represent one of the most promising ways to realise sustainable energy, whilst fuel cells provide the most efficient conversion device for converting hydrogen, and possibly other fuels, into electricity. Hydrogen and fuel cells open the way to integrated "open energy systems" that simultaneously address all of the major energy and environmental challenges, and have the flexibility to adapt to the diverse and intermittent renewable energy sources that will be available in the Europe of 2030."
"Europe should lead in undertaking rational analysis of alternative energy options and in demonstrating the benefits of a transition to a widespread use of hydrogen and fuel cells. They will have to provide cost-effective solutions to the following key challenges – the main drivers for Europe's future energy systems."

Five actions are identified. One of them is a European roadmap for hydrogen and fuel cells. These actions are explained and further detailed actions are given. Furthermore a rough sketch of the roadmap is given.

*Five actions to a hydrogen energy future:*

- *A political framework* that enables new technologies to gain market entry within the broader context of future transport and energy strategies and policies.
- *A Strategic Research Agenda*, at European level, guiding community and national programmes in a concerted way.
- *A deployment strategy* to move technology from the prototype stage through demonstration to commercialisation, by means of prestigious 'lighthouse' projects which would integrate stationary power and transport systems and form the backbone of a trans-European hydrogen infrastructure, enabling hydrogen vehicles to travel and refuel between Edinburgh and Athens, Lisbon and Helsinki.
- *A European roadmap for hydrogen and fuel cells* which guides the transition to a hydrogen future, considering options, and setting targets and decision points for research, demonstration, investment and commercialisation.
- *A European Hydrogen and Fuel Cell Technology Partnership,* steered by an *Advisory Council*, to provide advice, stimulate initiatives and monitor progress – as a means of guiding and implementing the above, based on consensus between stakeholders.

### Structure

The contents/structure of the document looks as follows.

- **Background document**
  By who and how the project is initiated, and a bit why
- **Foreword**
- **The Energy challenge**
  In this chapter the energy challenge is explained briefly. The role of hydrogen is mentioned.
- **Why hydrogen and fuel cells?**
  The requirements for a clean, safe and reliable secure energy supply in Europe. The role which hydrogen can fulfill is explained. In brief, hydrogen and electricity together represent one of the most promising ways to realize sustainable energy. The main challenges are treated (Energy security and supply, economic competitiveness, air quality and health improvements, greenhouse gas reduction)
- **What can Europe do?**
  In this chapter actions which should be executed are explained. The different 'themes' included are political framework, strategic research agenda, deployment strategy, European roadmap for hydrogen and fuel cells, hydrogen and fuel cell technology partnership. These themes are further elaborated, including a little more specific actions, to-do items. At the end of this chapter a kind of skeleton proposal for the European hydrogen and fuel cell roadmap is given.
- **Summary, conclusions and recommendations**

The roadmap has a clear structure. In the first chapters the background of the project is explained as well as the objectives. The reason why hydrogen technologies should be developed is included. In the chapter, "What can Europe do?" more detailed actions are specified. The document ends with a conclusion. The status of hydrogen technologies in Europe now is not elaborated.

### Topic and themes

The document mainly seems to focus on topics and themes related to coordinating, supporting the development of hydrogen technologies in Europe. So it focuses on the role the European Union and the countries within the European Union can have in leading, supporting the development.
The range of topics and themes addressed within is quite broad.
"The report highlights the need for strategic planning and increased effort on research, development and deployment of hydrogen and fuel cell technologies. It also makes wide-ranging recommendations for a more structured approach to European Energy **policy** and **research**, for **education and training**, and for developing **political and public awareness**." (page 6)
The topics and themes within the five main actions are:

- **Political** framework (The actions mentioned under this theme are all policy measures: support for demonstration/pilot projects; infrastructure, regulatory barriers to commercialization, codes and standards, international coordination)
- Strategic **research** agenda (The actions mentioned: designation centers of excellence, demonstration project, rules intellectual property, international cooperation, joint research programs, coordination, etcetera)
- A deployment strategy for hydrogen and fuel cells (Implementing and funding the transition to fuel cells, hydrogen)
- A European roadmap for hydrogen and fuel cells
- **Collaboration:** The European Hydrogen and Fuel Cell Technology Partnership

The focus is thus mainly on policies.

### Stakeholders

There is a wide range of stakeholders involved of multiple companies, research and public institutions. Many stakeholders are from companies.

"The High Level Group for Hydrogen and Fuel Cells Technologies was initiated in October 2002 by the Vice President of the European Commission, Loyola de Palacio, Commissioner for Energy and Transport, and Mr Philippe Busquin, Commissioner for Research. The group was invited to formulate a collective vision on the contribution that hydrogen and fuel cells could make to the realisation of sustainable energy systems in future." (page 5)
"The High Level Group, whose members are listed in Annex I, comprised 19 stakeholders representing the research community, industry, public authorities and end-users. The Group was requested to give a stakeholder, not a company view. The report was compiled with the assistance of the High Level Group Members' 'sherpas' and technical writers who are listed in Annex II." (page 5)

### Public

The main public of the roadmap seems to be the European Commission because the actions and advices are directed to the EC. The roadmap is made in order, for the EC. Probably the EC published it to inform all member states, and maybe also external countries and companies.

### Sender

The sender of this roadmap is the European Commission.

### Timeframe

The timeframe of the roadmap is a few decades. It is published in 2003 and the skeleton proposal for European hydrogen and fuel cell roadmaps runs until 2050. The actions mentioned are however more short term, up to 2010, 2020 and beyond 2020.

### Scope

The roadmap has a European scope.

Title: The Icelandic Hydrogen Energy Roadmap
Published: 2008
Organization: Icelandic Ministry of Industry and Commerce

### Purpose

Although the purpose of the document seems to be mentioned in the foreword, it's not sure whether this is the real purpose. Some sentences are literally copied from the National Hydrogen Energy Roadmap of the US DoE. Although it is said that the roadmap provide a blueprint, I don't agree. Actions are not really mentions or vaguely described in the chapters "moving forward". Furthermore the roadmap does not explore a wide range of activities.

"This Roadmap provides a blueprint for the coordinated, long-term, public and private efforts required for hydrogen economy development." (The Icelandic hydrogen Roadmap page 2, National Hydrogen Energy Roadmap, United States Department of Energy page i)
"The Ministry of Industry and Commerce initiated the roadmap process in an effort to coordinate the different parties that are working in the area and to highlight the desirable direction and tasks that need to be addressed for the hydrogen economy to become a reality in Iceland." (page 2)
"This roadmap is neither a government research and development plan nor an industrial commercialization plan. Rather, it explores the wide range of activities required to realize hydrogen's potential in solving Iceland's energy security, diversity, and environmental needs." (The Icelandic hydrogen Roadmap page 2 National Hydrogen Energy Roadmap United States Department of Energy page i)

So the exact purpose of the roadmap is not clear. Although the actions mentioned are not detailed, a vision suitable for Iceland is created in the roadmap. Also an idea about how to reach this vision and the challenges are mentioned. From this it can be concluded that the aim of the roadmap was to create a vision, which is shared among multiple important stakeholders and to think about how to get there. It is a kind of strategy, but not detailed yet. Furthermore the need for international collaborations emphasised multiple times. So it could also be that this document is meant to carry out a message to other countries than Iceland.

### Methodology

Nothing is said about the methodology. Probably the contents of the document result from a stakeholder discussion. For each element of the hydrogen economy, production, storage and conversion and application a vision and some (no really detailed) actions are defined.

### Structure

A summary of the structure of the roadmap is given below. Four chapters are devoted to an element of the 'hydrogen economy' (hydrogen production, hydrogen storage, infrastructure and conversion and application). For each element the status now (world and in Iceland) is shortly described, the challenges, the vision/strategy and how to move forward. This is a clear structure and looks like the structure of the Hydrogen Energy roadmap of the US DOE. It seems like the document doesn't have a real conclusion. I don't see the chapter "hydrogen research" as a conclusion.

- **Foreword**
  It's explained why the roadmap is made and the purpose of the roadmap is explained
- **A vision for the future today, From the Icelandic Ministry of Industry and Commerce**
  In this part it is written what the government has done until now, so the commitment of the government. Also the importance of the involvement in an international platform for hydrogen research is emphasized.
- **Some Facts Iceland – Energy – Hydrogen**
- **Hydrogen production** (Current status, Key Challenges, Vision/Strategy, Moving forward)
- **Hydrogen storage** (Current status, Key Challenges, Vision/Strategy, Moving forward)
- **Infrastructure** (Current status, Key Challenges, Vision/Strategy, Moving forward)
- **Conversion and Application** (Current status, Key Challenges, Vision/Strategy, Moving forward)
- **Hydrogen Research**

Need research, international collaboration, the needs for hydrogen production, hydrogen delivery and distribution, socio economic, hydrogen storage, international research.

### Topic and themes

This roadmap is prepared for the Icelandic Ministry of Industry and Commerce. The roadmap focuses on technological, economic issues. International collaboration is an important topic. It is discussed on page three, and the importance is emphasized multiple times throughout the document.

"Emphasis will be laid on international consultation and co-operation as the problems to be solved are global in nature. Iceland realizes the importance of working with others on the hydrogen issue to make it an integral part of a global agenda to succeed." (page 3)

In the chapter's hydrogen production, storage, infrastructure, conversion and applications the focus is on cost effective solutions and the support the government should provide to develop for example demonstrations. Also collaboration with global leaders in R&D is mentioned. In the chapter storage the public perception is also mentioned as a barrier. In the last chapter research needs are addressed. This does not only focus on technical issues like the hydrogen production, delivery and distribution and storage. Also the need socio economic research is mentioned.

### Stakeholders

Multiple stakeholders are involved, mentioned on the front page as "Contributors". These stakeholders are from the following companies and institutions. Reykjavik university, National Energy Authority, Ministry of Industry Energy and Tourism, Landsvirkjun (Iceland's leading energy company producing electricity from renewable hydro and geothermal sources), Orkuveita Reykjavíkur (public utility company providing electricity, geothermal water for heating, cold water for consumption and fire fighting), Innovation centre Island, Varmaraf (develops hydrogen storage devices based on metal hydrides), Icelandic New Energy Promoting Hydrogen in Iceland, Skeljungur Ltd. (oil importing company, range of retail and service operations in Iceland), Ministry for Foreign Affairs, University of Iceland. So a broad range of stakeholders is involved. It is not clear in which way these stakeholders were involved.

### Public

The public of the roadmap does not become fully clear from the contents. The "moving forwards" chapters are aimed at what the government is going to do. Also in the beginning of the document is it's written what the government is going to do, should do. The roadmap is prepared for the Icelandic Ministry of Industry and Commerce. So probably the document is mainly meant for this ministry.

### Sender

It's not really clear who the sender of the document is. The roadmap was found on the site of Olafur Ingolfsson, a professor of glacial and quaternary geology at the University of Iceland, department of Geology and Geography. Probably the Icelandic government can be considered as the sender.

### Timeframe

Timeframes are not explicitly mentioned in this document. The timeframe of the roadmap is not clear.

### Scope

The scope of this roadmap is national, although multiple times the importance of international collaboration (especially for R&D) is sited and referred to developments in the US and Europe (mainland).

### Comments

- The amount of text is not too large
- No detailed actions, no timeline. Actions are only vaguely described in the chapter "moving forward"

Title: Texas Hydrogen Roadmap
Published: 2009
Organization: Houston Advanced Research Centre

**Purpose**

Only one purpose of the roadmap or roadmapping process is mentioned in the text.
"The Texas Roadmap planning process identified advantages that distinguish the state's potential to use hydrogen as a transportation fuel."

So one of the goals is to identify the reasons why Texas should develop hydrogen technologies, to identify the opportunities for Texas.
Texas is not putting a lot of effort in developing hydrogen technologies until now. Sometimes it looks like the tone of the document is to convince stakeholders to put more effort into it. This does not only appear from the document, but also two organizations involved in making this roadmap, are pro-hydrogen technologies. So probably one of the most important purposes of this roadmap is to convince the government that they should put some effort in developing hydrogen technologies.

- In the executive summary it is said that "Hydrogen is one of several leading options …" and that "Hydrogen would not cost any more per mile than gasoline used today" which is concluded in a report of General Motors and Shell Hydrogen. Furthermore it is mentioned that other states adopt strategies and hydrogen roadmaps. Also the advantages of Texas regarding the potential to use hydrogen as a transportation fuel are mentioned.
- In the chapter "Texas Challenges" is shown in a table that Texas has few incentives specifically aimed at hydrogen.

"With the exception of South Carolina, Texas has few incentives specifically aimed at hydrogen energy applications. The exception, South Carolina, has pursued a successful economic development and research strategy for hydrogen and fuel cells. The state has provided funding toward these efforts, but more importantly they have targeted organizational efforts that are supported by several public and private sector entities." (page 5)

- Also in other parts of the text, indication can be found for the fact that this roadmap is meant to convince decision makers to invest in and enable hydrogen technologies.

"In Texas, economic development benefits alone would seem to be a sufficient driving force for considering hydrogen as part of its energy future. There is a logical match with Texas production, resources, knowledge and experience. Texas has plentiful resources for new strategies that respond to energy sector challenges and opportunities. These responses can build on Texas strengths and advantages summarized in this report, while beginning to ease some of the driving forces." (page 16)

Probably one of the goals is also to analyse the future using scenarios, to identify some actions which can be executed to accelerate the development of hydrogen technologies and to inform. The scenarios calculate the hydrogen fuel consumed, gasoline fuel displaced and the net greenhouse gas reductions over time.

**Methodology**

There has been a workshop, to discuss a set of topics. Six key questions were answered by stakeholders in workshops. Which questions these are is not mentioned, but the advantages of hydrogen technologies as well as the possible actions are discussed. Also three scenarios are developed and modelled by the NREL. For these three scenarios the hydrogen fuel consumed, gasoline fuel displaced and the greenhouse gas emissions are calculated. For each scenario an action list is given. Based on these routes eight near-term actions are recommended.

"This project was funded through the State Energy Conservation Office (SECO) with support from the Texas H2 Coalition and the National Renewable Energy Lab (NREL). A stakeholder workshop was held in August 2008 to hear from experts and to review a wide range of hydrogen and fuel cell topics. The forty participants included industry representatives, federal agencies, state and local governments, and researchers and technologists. About half were from Texas and half from other areas involved in hydrogen. Following presentations, participants divided into discussion groups to respond to six key questions about the Texas hydrogen roadmap, identifying advantages that the state has and discussing actions, both near and long term that fit Texas circumstances. The workshop and follow- up discussions, reviews of hydrogen plans, studies and projects, modelling analysis from

the National Renewable Energy Lab, and HARC research staff input produced this document, which sets forth three alternative routes for Texas to consider. Out of a broader framework in light of activities nationally and in other states, eight actions have been identified for immediate consideration. " (page 1)

### Structure

The structure of the Texas hydrogen roadmap is not very clear, logical. The structure is summarized below. It's not clear why the two small pieces of text (Texas Challenges and Texas hydrogen Roadmap Goals) are at the beginning of the document, which purpose that serves. The executive summary is not really a summary of the document, but more to convince something should be done to develop hydrogen technologies. Furthermore the methodology is explained (which is not explained anywhere else more extensively). It is strange that the last three chapters are the last chapters. I would expect them to be at the beginning of the document (advantages, current/past projects and basic information). To me it's not clear what the chapter "Texas Hydrogen Markets: Production and use" contents. It was also not clear directly how the near term action were determined. The contents of the chapters are not introduced very well, the chapters are in a strange order and they seem to be a bit independent of each other.

- **Texas Challenges** (short)
  The energy challenges for Texas are enumerated: the high fuel use, electricity use and greenhouse gas emissions.
- **Texas Hydrogen Roadmap Goals**
  The goals stated in this part are not really the goals of the roadmap document or process themselves. If these goals are achieved, this "would establish hydrogen production and demand as a larger part of a Texas energy portfolio."
- **Executive summary**
  In the executive summary the development of hydrogen technologies in general is shortly explained and what Texas can do. This purpose of this part of text seems to convince the reader. Also the methodology of this roadmap is explained in the executive summary
- **Texas Challenges**
  The challenges of Texas are mentioned and explained a bit more extensively. At the end of this chapter it is shown that Texas doesn't have a lot of incentives for hydrogen production compared to other states, and other states are ahead of them with regard to hydrogen technologies.
- **Routes on the Texas Hydrogen Roadmap**
  Three scenarios, three routes are defined for the development of hydrogen technologies. In this chapter these routes are explained and the associated actions are given. Also the benefits of hydrogen are displayed in a box.
- **Gasoline and Greenhouse Gas Reductions by Route**
  In this chapter two graphs are included which show the reduction of greenhouse gasses in all three scenarios. This is explained in the text.
- **Near Term Actions: 2009 and 2010**
  In this chapter some near term actions are defined "that would put Texas in a much more competitive position than it is today with respect to hydrogen". –These follow from the scenarios described above.
- **Texas Hydrogen Markets: Production and use**
  It is not clear to me what is explained in this chapter. Maybe it's the vision?
- **Hydrogen Basic Information**
  In this chapter basic information of hydrogen technologies and possible applications in Texas are explained.
- **Texas hydrogen Advantages**
  The advantages for Texas to develop hydrogen technologies are enumerated and explained.
- **Texas hydrogen Experience**

In this chapter the current and past projects on the development of hydrogen technologies are elaborated.

### Topic and themes

Because the roadmap is aimed at the government, mainly policies are covered. This can be concluded from the near term actions:

1. Designate a key hydrogen contact within State government
2. Adopt and promulgate a Texas hydrogen and fuel cell plan
3. Develop and support deployment projects.
4. Provide incentives for expanded hydrogen production with special attention to the role of renewable sources.
5. Support military applications for hydrogen market transformation projects.
6. Launch reviews of codes and ordinance to identify existing barriers to hydrogen applications.
7. Incorporate fuel cells and hydrogen in state purchasing guidelines.
8. Modify air quality incentive programs to encourage hydrogen use in nonattainment regions.

Subjects like R&D, public outreach and education are not are not discussed.

### Stakeholders

A list of workshop participants is given in the appendix. 41 stakeholders are mentioned, these are companies, research institutions and universities. These stakeholders were involved through a workshop. It is not clear what was discussed in this workshop.
"A stakeholder workshop was held in August 2008 to hear from experts and to review a wide range of hydrogen and fuel cell topics. The forty participants included industry representatives, federal agencies, state and local governments, and researchers and technologists. About half were from Texas and half from other areas involved in hydrogen." (page 1)

### Public

The public of this roadmap is the government. The eight near term actions defined are aimed at the government.

### Sender

The sender of the project is the Houston Advanced Research Centre (HARC).

"HARC is a not-for-profit organization based in The Woodlands, Texas dedicated to improving human and ecosystem well-being through the application of sustainability science and principles of sustainable development. HARC's mission is to move knowledge to action to improve human well-being and the environment." [1]
It is a project for the State Energy Conservation Office, State of Texas
"The mission of the State Energy Conservation Office (SECO) is to maximize energy efficiency while protecting the environment. SECO administers and delivers a variety of energy efficiency and renewable energy programs that significantly reduce energy cost and consumption in the institutional, industrial, transportation and residential sectors." [2]

Furthermore, the Texas H2 Coalition, National Renewable Energy Laboratory and the U.S. Department of Energy support the project.
"The Coalition and its membership are focused on advancing the infrastructure that is needed for large-scale hydrogen production, storage and distribution which will reduce environmental pollution and fossil fuel dependency.This can be achieved in Texas by first capturing near-term, commercially available technologies that use large volumes of hydrogen, creating an immediate hydrogen demand as a commodity."
It is should be noticed that two parties are involved which are positive towards the hydrogen economy.

### Timeframe

The time frame of the scenarios is a few decades, from 2009 when the roadmap was published to 2050. The actions mentioned in the document are near term: 2009, 2010.

### Scope

The roadmap focuses solely on Texas.

[1] http://www.harc.edu/AboutHARC/tabid/54/Default.aspx, consulted 23 July 2012
[2] http://seco.cpa.state.tx.us/about/, consulted 23 July 2012
[3] http://www.texash2coalition.com/About/

Title: National Hydrogen Energy Roadmap
Published: 2002
Organization: United States Department of Energy

**Purpose**

The roadmapping process and the document have a few purposes. First it maps the actions which are required to develop the hydrogen economy and identifies the strategic goals, barriers, and key activities. For involved stakeholders it gives an overview of what should be done. Another important goal is to give direction to the hydrogen development, a direction which is shared among stakeholders. So a common agenda is created. Possibly also the creation of partnership between governmental organizations and industry is one of the purposes.

"This Roadmap provides a **blueprint for the** coordinated, long-term, public and private **efforts required** for hydrogen energy development" (page i)
"This Roadmap is neither a government research and development plan nor an industrial commercialization plan. Rather, it **explores the wide range of activities required** to realize hydrogen's potential in solving U.S. energy security, diversity, and environmental needs. It is intended to **inspire the organizations that invest in hydrogen energy systems**—public and private, State and Federal, businesses and interest groups—to become involved in a coordinated effort to reduce risk, improve performance, decrease cost, and implement a secure, clean, and reliable energy future." (Page i)
"Developing hydrogen as a realistic energy option will necessitate an unprecedented level of **sustained and coordinated activities by diverse stakeholders**. Recognizing the need to develop a **coordinated national agenda**, the U.S. Department of Energy initiated a National Hydrogen Vision and Roadmap process to incorporate the opinions and viewpoints of a broad cross-section of those stakeholders. The process involved two key meetings: the National Hydrogen Vision Meeting and the National Hydrogen Energy Roadmap Workshop." (Page 1)
"This Roadmap is a product of the workshop. It is intended to help **identify the strategic goals, barriers, and key activities** required to evaluate the costs and benefits of a hydrogen economy and to lay **a foundation for the public-private partnerships** needed to implement the plan." (Page 3)
"The fundamental purpose of this Roadmap is to **define a common set of objectives and activities** agreed upon by government, industry, universities, National Laboratories, environmental organizations, and other interested parties. Focusing resources on this **common agenda** will facilitate evaluation of a hydrogen economy and potentially stimulate investment in the development of a hydrogen energy system." (Page 39)
"**Strong government-industry partnerships** are needed to evaluate the potential for hydrogen to play a larger role in America's energy future." (Page 39)
"Implementation of this Roadmap involves making progress on the top priority actions and recommendations. Only by **working together**—government, industry, universities, National Laboratories, and environmental organizations—will progress be made." (Page 41)
"The aims of the meeting were to identify a **common vision** for the hydrogen economy, the time frame in which such a vision could be expected to occur, and the key milestones for achieving it." (National Vision document)

### Methodology

The methodology is explained briefly in the introduction. There were two key meetings: the national hydrogen vision meeting and the national hydrogen energy roadmap workshop. A large amount of stakeholders was involved in this workshop. Two separate documents are written, “A National Vision of America’s Transition to a Hydrogen Economy – to 2030 and beyond” and “National Hydrogen Energy Roadmap”. The roadmap is considered as a follow up of the meeting on the vision.

“The U.S. Department of Energy initiated a National Hydrogen Vision and Roadmap process in response to recommendations in the *National Energy Policy*. The first step in that process resulted in publication of the *National Vision of America’s Transition to a Hydrogen Economy (*February 2002). This Roadmap represents the next step in that process.” (page i)
“Developing hydrogen as a realistic energy option will necessitate an unprecedented level of sustained and coordinated activities by diverse stakeholders. Recognizing the need to develop a coordinated national agenda, the U.S. Department of Energy initiated a National Hydrogen Vision and Roadmap process to incorporate the opinions and viewpoints of a broad cross-section of those stakeholders. The process involved two key meetings: the National Hydrogen Vision Meeting and the National Hydrogen Energy Roadmap Workshop.” (page 1)
National Hydrogen Vision Meeting:
“The National Hydrogen Vision Meeting was held on November 15-16, 2001, in Washington, DC. Participants included more than 50 business executives and public policy leaders from Federal and State agencies, the U.S. Congress, and environmental organizations. The U.S. Department of Energy initiated the meeting in response to recommendations in the National Energy Policy regarding hydrogen technologies. The aims of the meeting were to identify a common vision for the hydrogen economy, the time frame in which such a vision could be expected to occur, and the key milestones for achieving it.” (page 2)
National Hydrogen Energy Roadmap:
“The National Hydrogen Energy Roadmap Workshop took place on April 2 –3, 2002, in Washington, D.C. Approximately 220 technical experts and industry practitioners from public and private organizations participated in the meeting (a list of participating organizations is located in the Appendix). Seven leaders from industry and academia with expertise in hydrogen systems helped guide the subsequent roadmap development process. During the workshop, participants divided into breakout groups based on the roadmap segments. They discussed key needs that should be addressed in order to achieve the Vision; appropriate roles for industry, government, universities, and National Laboratories; development of public-private partnerships; and time frames for the activities.” (page 3)

### Structure

The report has a clear structure, which is summarized below. The basic structure is standard: an introduction, the contents and a conclusion. First a chapter is written about system integration. Than some segments of hydrogen technology are treated: production, delivery, storage and conversion. In the last two chapters the education and outreach are treated. These last two chapters and the chapters on production, delivery, storage and conversion have the same set up. The situation today, the vision, the challenges and the path forward are explained and the chapters end with a small conclusion.

- **Plan of action** (foreword)
- **Executive summary**
- **Introduction**
  Benefits hydrogen; challenges; need for coordination of activities; vision meeting and outcomes; roadmap meeting and purpose document (why hydrogen; why roadmap; methodology: explanation project)
- **Systems integration**
  Issues/actions related to system integration are addressed. Short chapter
- **Production**
  Situation today, vision, challenges, paths forward (actions), conclusion
- **Delivery**
  Situation today, vision, challenges, paths forward (actions), conclusion
- **Storage**
  Situation today, vision, challenges, paths forward (actions), conclusion
- **Conversion**
  Situation today, vision, challenges, paths forward (actions), conclusion

- **Applications**
  Situation today, vision, challenges, paths forward (actions), conclusion
- **Education and outreach**
  Situation today, vision, challenges, paths forward (actions), conclusion
- **Conclusions**

"The following chapters reflect the ideas and priorities put forth by the workshop participants. Each chapter is focused on an industry segment and provides a description of current status, challenges to achieving the vision, and paths forward." (page 9)

### Topic and themes

The document is structured elaborating on the different segments of the hydrogen economy: systems integration, production, delivery, storage, conversion, applications, education and outreach. Within these segments, multiple topics and themes are treated, although the focus seems to be on research and development, on technical issues.
For the segments production, delivery, storage and conversion the focus is mainly on research, development and demonstration to improve techniques. In these chapters also government support for research, development and deployment are mentioned. In the chapter of hydrogen storage, the need to develop a coordinated national program is also mentioned.
The chapter "Applications" focuses on customer awareness and acceptance, next to cost and performance issues. This chapter also focuses on supportive energy and environmental policies. So the actions are aimed on demonstrations, regulations, codes and standards to foster customer acceptance and public policies.
The last chapter is fully devoted to public education and outreach

### Stakeholders

An extensive list of stakeholders is given in the appendix. Over 130 stakeholders were involved. This list includes a broad range of stakeholders including companies, universities, and governmental institutions.

"The National Hydrogen Energy Roadmap Workshop took place on April 2 –3, 2002, in Washington, D.C. Approximately 220 technical experts and industry practitioners from public and private organizations participated in the meeting (a list of participating organizations is located in the Appendix). Seven leaders from industry and academia with expertise in hydrogen systems helped guide the subsequent roadmap development process." (page 3)
"The efforts of the 53 business executives, Federal and State energy policy officials, and leaders of universities, environmental organizations, and National Laboratories who contributed to the development of this vision document by offering their views at the National Hydrogen Vision Meeting are deeply appreciated." (National Vision document)

### Public

The public of this roadmap consist of all involved parties, as can be seen in the quotes below. Furthermore the cooperation between government and industry is often mentioned.
"This Roadmap is neither a government research and development plan nor an industrial commercialization plan. Rather, it explores the wide range of activities required to realize hydrogen's potential in solving U.S. energy security, diversity, and environmental needs. It is intended to inspire **the organizations that invest in hydrogen energy systems—public and private, State and Federal, businesses and interest groups**—to become involved in a coordinated effort to reduce risk, improve performance, decrease cost, and implement a secure, clean, and reliable energy future." (page i)
"Implementation of this Roadmap involves making progress on the top priority actions and recommendations. Only by working together—**government, industry, universities, National Laboratories, and environmental organizations**—will progress be made." (page 41)
"This roadmap outlines key issues and challenges in hydrogen energy development and suggests paths that **government and industry** can take to expand use of hydrogen-based energy." (page iii)

### Sender

The sender of the roadmap is the United States department of Energy. The U.S. Department of Energy initiated this national hydrogen vision and roadmap process.

### Timeframe

The timeframe of the vision is a few decades: approximately to 2030, 2040. It is not clear what the timeframe of the roadmap is.

**Scope**

The roadmap has a national scope. The scope is the entire United States.

Title: HyWays the European Hydrogen Roadmap
Published: 2007
Organization: Ludwig-Bölkow-Systemtechnik (coordinator)

### Purpose

The purpose of the roadmap is to inform the government, inform decision makers. It is a kind of strategy. In the last quote below it is said that the aim is to develop a "validated and well accepted" roadmap. So probably one of the purposes is to create an aligned vision.

"A major goal of the HyWays technical analysis was to identify the selection of hydrogen supply chains (= pathways) to understand the variations from country to country as well as overlaps or differences for Europe. The selection process was a cornerstone of the vision development in each of the 10 countries." (Roadmap, page 20)
"The HyWays project sets out to produce a roadmap for Europe, that clearly demonstrates the **advantages and problems** posed by this very innovative energy technology option, alongside the **timings and expected costs**. An Action Plan accompanying the Roadmap details the conditions, including **measures and their timelines, necessary to overcome the initial barriers** in order to facilitate the deployment of hydrogen technologies. The Action Plan addresses politicians and policy makers at a national and European level and is designed to **inform decision makers** with respect to governmental support during the initial phase." (Roadmap, page 8)
The HyWays Roadmap and Action Plan for hydrogen in Europe provide a **strategy to overcome these barriers**. (Roadmap, page 1)
The Action Plan – this report – outlines the **policy actions needed** to initiate and facilitate the desired transition. (Action plan page 4)
"The project **explores and plans for the potential that the integration of hydrogen technologies into the energy system have** to contribute to the challenges of ensuring that Europe's peoples and economies have a secure, environmentally sustainable and economically competitive supply of energy services for generations to come." (Roadmap page 8)
The **interests of ministries**, which sooner or later will have to deal directly or indirectly with the consequences of the introduction of hydrogen, **need to be aligned** upfront. (Action plan, page 1)
"HyWays has the aim to develop a **validated and well accepted** roadmap for the introduction of hydrogen in the energy system." (Roadmap, page 8)
Part of the roadmap is possibly also to convince policy makers that they should invest more in the emergence of a hydrogen economy. Below part of the summary is cited.
"The HyWays Roadmap has outlined that as a result of the introduction of hydrogen into the energy system, substantial emission reduction can be achieved in a cost effective way, see (HyWays, 2007). At the same time, security of supply is improved and new economic opportunities are created. Despite the advantages, initial barriers prevent hydrogen from entering the energy system at a sufficient rate **if no further policy incentives are provided**. This Action Plan, developed based on the HyWays Roadmap, gives concrete **policy actions** that need to be taken to enable hydrogen to overcome smoothly these initial barriers.
**Immediate action** is needed to decrease the vulnerability of the economy to shocks in and/or structurally high oil prices as well as to ensure that the full potential offered by hydrogen as an emission reduction option is utilised. Yet, hydrogen is **insufficiently high on the agenda of policy makers**. As a result, the required **deployment support is still lacking**. The interests of ministries, which sooner or later will have to deal directly or indirectly with the consequences of the introduction of hydrogen, need to be aligned upfront. This will prevent delay as the technology progresses through the various transition phases before reaching full commercialisation.
Large-scale demonstration projects can play a key role in **convincing policy makers** that the performance of hydrogen technologies is progressing fast and has the potential to emerge quickly from the R&D-stage into the pre-commercial phase. A **hydrogen support framework** should therefore be implemented with highest priority. However, this might take several years. At present, large-scale demonstration projects are already being prepared. A public-private partnership, such as a Joint Technology Initiative (JTI), can bridge the period until the required support scheme is operational. Within such a public-private partnership, R&D and deployment support go hand in hand." (Action Plan, page 1)

### Methodology

A selection of member states (Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain and the United Kingdom) gave input. This input is used when modelling the future, when constructing scenarios. From these scenarios needed policies are derived. Furthermore in the action plan also a large amount of stakeholders is involved, which are mentioned at the end of the document: the HyWays consortium. These consist of people from industry, research institutes and member state representatives.

"The HyWays project combines technology databases and socio-/ techno-/ economic analyses to evaluate selected stakeholder scenarios for future sustainable hydrogen energy systems. Scenarios are based on member states (MS) visions for the introduction of hydrogen technologies with extensive interaction between science and stakeholders involving over 50 workshops. For each country the theoretical economic optimum choice is calculated and evaluated by the member states on an iterative basis. A multinational approach covering, at that time, 80% of the EU land area and over 70% of the population ensures a wide diversity in terms of feedstocks, regional & infrastructure-related conditions and preferences. "

"The HyWays project compiles all pivotal technological and socio-economic aspects related to a future hydrogen infrastructure build-up and provides a number of scenarios under different assumptions. It shows the consequences of the introduction of hydrogen as a fuel and indicates the financial effort necessary to reach the break-even point.

The HyWays project differs from other road mapping exercises as it integrates stakeholder preferences, obtained from multiple member state workshops, with extensive modelling in an iterative way covering both technological and socio-economic aspects, see Figure 1.1. This approach enables qualitative data to be incorporated in a systematic and structured manner with quantitative infrastructure analysis, thus adding significantly to the common quantitative modelling approach adopted by other roadmaps.

The stakeholder validation process, which takes into account country specific conditions, is a key element of the road mapping process.

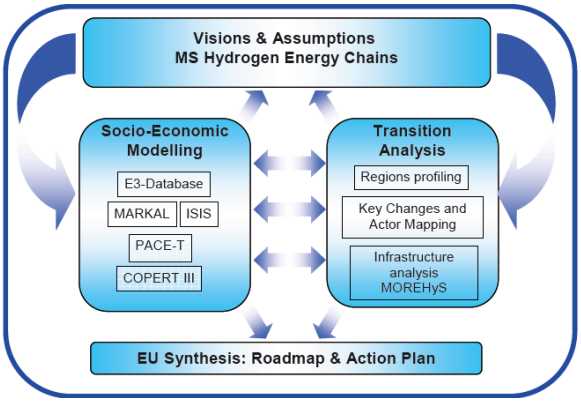



*Figure 1.1 Schematic representation of the HyWays process*

In the HyWays project the Roadmap is based primarily on country-specific analyses of ten member states (MS) (six in HyWays phase I and four in HyWays phase II). The countries selected (Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain and the United Kingdom) ensure a large coverage, both in land and population, and represent the diversity and geographical spread of Europe, increasing the confidence in the validity of the synthesis at European level." (Roadmap page 8, 9)

"HyWays has not performed a simulation, in a sense that the penetration rate is a function of the cost-effectiveness of the hydrogen technology. The aim of HyWays was to build a roadmap for the introduction of hydrogen in the energy system. Consequently, the penetration of hydrogen applications was the starting point, not the result of the exercise. This back casting type of approach is a common way in roadmap building.7 Based on the deployment scenarios, HyWays has explored the consequences of hydrogen entering the energy system with respect to, economics, environmental benefits and employment as well as build-up of a hydrogen infrastructure and consequences for the energy sector. As a final step, a policy framework to enable the hydrogen transition was developed with a specific focus on how to initiate the transition. (Roadmap, page 15)

7 By using a back casting approach and taking hydrogen deployment as starting point, a number of complex methodological problems could be avoided (specifically with respect of purchase behaviour) that are in general part of a simulation approach. If the policy framework was taken as a starting point, modelling its effect would have to be oversimplified by translating it into economic impacts only. The (limited rationality of) purchase behaviour and oversimplification of policy framework would lead to a very large uncertainty in the development of the penetration rates, ignoring the fact that the (hydrogen specific) policy framework specifically in the early phase"

### Structure

Two reports are studied: the Hyways action plan and the Hyways roadmap.
"The HyWays Roadmap provides a detailed sketch of the build-up of a hydrogen energy system. The Action Plan – this report – outlines the policy actions needed to initiate and facilitate the desired transition." (Actionplan, page 4)
In the roadmap the focus is on the scenario analysis and the outcomes of this analysis. The actionplan discusses what should happen, the implementation of policies and issues related to that.
The structure of the roadmap looks as follows:

- **Summary**
- **Introduction** (explaining the background of the project, the objective, the applied methodology, alternatives for hydrogen technologies, other initiatives, projects)
- **Hydrogen end-use applications** (deployment scenarios for hydrogen end-use applications as well as expected technological progress are described, an analysis is done using input from scenario's)
- **Infrastructure build-up and hydrogen production mix** (in this chapter the future development of an infrastructure is explained)
- **Economic impacts** (economic effects of the scenarios)
- **Implications for research** (research priorities, targets as well technical as socio-economic, summary of the deployment phases, targets and main actions based on the Roadmap and Action plan)
- **Summary of the Action Plan**

The structure of the action plan looks as follows:

- **Summary**
- **Introduction** (need for a roadmap, methodology/approach)
- **Summary of the HyWays Roadmap** (the member state visions, the two main barriers, what can be achieved: emission reduction; security of supply; sustainable use fossil fuels; contribution to targets for …)
- **The need for a hydrogen support scheme** (main challenges to be tackled, general scope of the policy support framework: deployment support, cost reductions, monitor efforts, ensure a plying field; characteristics support framework
- **A hydrogen specific support framework** (the need of a tailor-made approach, link to support schemes for renewable energy and sustainable transport, public-private partnership, the role of early markets and niche markets. For each chapter, actions and recommendations are mentioned)
- **Concrete incentives to enable the introduction of hydrogen technology**. (Incentives to be implemented at the EU, national and local/regional level are discussed, no bullet-point actions)
- **Actions needed to facilitate the introduction of hydrogen** (Kind of summary, overview of actions which are all needed.

"This report comprises the Action Plan. The Action Plan is closely linked to the HyWays Hydrogen Roadmap and the Member States' Vision Report. Therefore, first a short summary of the HyWays Roadmap is given (chapter 2). Next, the need for a hydrogen support scheme is outlined and the general scope of the support scheme is described. In chapter 4, the basic characteristics of a hydrogen support scheme are presented, followed by a description of potential measures to be implemented at various policy levels (chapter 5). The report concludes with a list of main actions that need to be take in order to overcome the initial barriers that prevent hydrogen from entering the energy system at a sufficient rate." (Action plan, page 5)
The structure of both documents is not very clear.

### Topic and themes

The main focus is on policy. Within these policies different themes are addressed: Research and Development, Deployment, Regulations (Tax, market, codes and standards), education and training for employment, synergies with other options, infrastructure build-up, and alignment of interests)

### Stakeholders

Stakeholders from as well industry and research institutes were involved. Also Member state representatives are involved in the project. It is noticeable however that these member state representatives are not directly from governments, but from institutes. So the government does not seem to be involved. Probably people from these institutes have more insight into the techniques and the possible future compared to policy makers.

### Public

This roadmap is made for government, decision makers.
"The Action Plan addresses politicians and policy makers at a national and European level and is designed to inform decision makers with respect to governmental support during the initial phase." (Roadmap, page 8)

### Sender

The roadmap doesn't have a clear sender. The project is financed by research institutes, industry, national agencies and the European Commission.
"HyWays is an integrated project, co-funded by research institutes, industry, national agencies and by the European Commission (EC) under the 6$^{th}$ Framework Programme [contract No502596]."
Ludwig-Bölkow-Systemtechnik (LBST) is the coordinator of the project. This is a consultancy firm.

### Timeframe

The timeframe of this roadmap is a few decades, to 2050. The actions in the action plan focus on more near term actions.
"The Action Plan addresses politicians and policy makers at a national and European level and is designed to inform decision makers with respect to governmental support during the **initial phase**." (Roadmap, page 8)

### Scope

In general the scope is European. The HyWays project is a European project. In the vision contributions of separate member states are included. So although the scope is European, preferences and differences of the member state countries are taken into account. This becomes most clear when reading the vision report.

### Comments

- The two documents studied, the action plan and the roadmap, sometimes overlap. Furthermore, within both document, issues are mentioned double, multiple times. Reading the summary report is most effective.
- There are three important documents: The Action Plan is closely linked to the HyWays Hydrogen Roadmap and the Member States' Vision Report.

## C. Geothermal energy technology roadmaps

Title: Technology Roadmap, Geothermal Heat and Power
Published: 2011
Organization: International Energy Agency

### Purpose

By identifying the actions needed a strategy is outlined.

"The roadmap identifies the **primary actions and tasks** that must be addressed to **accelerate geothermal development** globally."
The tone of the document is quite pro-geothermal. One of the aims is also to accelerate the geothermal development.
"This roadmap is intended to help **drive these necessary developments**."
"The goal is to **accelerate the overall RDD&D** process in order to enable earlier commercial adoption of the technology in question."
Maybe also one of the aims is to convince stakeholders that they should invest in geothermal energy technologies.
"The overall aim of these roadmaps is to **demonstrate the critical role** of energy technologies in achieving the stated goal of halving energy-related carbon dioxide ($CO_2$) emissions by 2050. The roadmaps will enable governments, industry and financial partners to **identify the practical steps** they can take to participate fully in the collective effort required"

### Methodology

The methodology is not explained extensively. The following is said in the paragraph "Purpose, process and structure of this roadmap"

"The IEA first Geothermal Roadmap Workshop (8 April 2010, Paris) focused on technology development. A second workshop (24 October 2010, Sacramento, California) as a side event to the Geothermal Resource Council's annual meeting, focused on the policy framework needed to overcome economic and non-economic barriers. A third workshop (29 November 2010, Bandung, Indonesia) sought to establish conclusions from the first two workshops and a case study of geothermal development in Indonesia."
So two workshops are held, which focussed on technology development and the policy framework. A third workshop focuses to establish conclusion (consensus?).The vision was developed by a scenario.
"For this roadmap, the *ETP 2010* BLUE Map Hi-REN scenario was chosen as the basis for the projection of geothermal power by 2050 (Box 5)."

From the acknowledgements also some things about the methodology can be deduced. People from within IEA and representatives of the IEA worked on the development of the roadmap. Numerous experts provided the author with information and/or comments on working drafts. Also people were involved in the workshop.

### Structure

The structure of this roadmap is very clear. The order of the different elements is logical: situation today, vision, actions and milestones. Furthermore it's also clearly explained throughout the text. Below summarizes the structure and contents of the document.

**Foreword**
In the forward, the need for action is emphasized as well as the origin of the road mapping process. Also geothermal energy technology is shortly explained
**Acknowledgements**
**Key findings**
In the key findings the targets for geothermal need to achieve certain goals concerning $CO_2$ emissions and climate change are mentioned and some needs are mentioned.
**Introduction**
In the introduction the background of the project is mentioned as well as the purpose of the roadmap. It is explained why geothermal energy should be developed further and the technology is also explained. Again the purpose is shortly explained as well as the structure. The methodology is explained very briefly.

**Geothermal energy today**
The history of geothermal energy and how much the technology is exploited today is told. Furthermore the potential for geothermal energy is explained looking at as well hydrothermal sources and hot rock sources (last type not yet in the commercial phase). Also current technologies are discussed: the type of power plants used the possible uses of geothermal energy and the use today. Resource assessment and accessing and engineering the resource are mentioned probably because of the importance of these two subjects. A paragraph is devoted to the economics today, commenting on the competitiveness of geothermal, and the investment costs, operation and maintenance costs, production cost and cost of financing.
**Vision for deployment and $CO_2$ abatement**
In this chapter the scenarios and vision are extensively explained (as well as deployment as economic issues)
**Technology development: actions and milestones**
The technological actions are structured by subject: geothermal resource assessment, accessing and engineering the resource, geothermal heat use, advanced geothermal technologies (EGS), advanced geothermal technologies: other. First the actions, including timeframes and actors which should execute these actions are presented in a table, followed by text in which the actions are explained.
**Policy framework: actions and milestones**
The actions related to the policy framework are structured by subject: regulatory framework and support incentives, market facilitations and transformation, research, development and demonstration support, international collaboration and deployment in developing economies. First the actions, including timeframes and actors which should execute these actions are presented in a table, followed by text in which the actions are explained.
**Conclusion and role stakeholders**
In this last chapter the actions which are needed are summarized. This time not on subject, but on stakeholder which needs to execute these actions.

## Topic and themes

Mainly technical, economical and policy frameworks are explained.

**Technical**
potential for geothermal energy is explained looking at as well hydrothermal sources and hot rock sources (last type not yet in the commercial phase). Also current technologies are discussed: the type of power plants used the possible uses of geothermal energy and the use today. Resource assessment and accessing and engineering the resource are mentioned probably because of the importance of these two subjects.
In the vision the geothermal deployment is explained.
The technological actions are structured by subject: geothermal resource assessment, accessing and engineering the resource, geothermal heat use, advanced geothermal technologies (EGS), advanced geothermal technologies: other. First the actions, including timeframes and actors which should execute these actions are presented in a table, followed by text in which the actions are explained.

**Economical**
A paragraph is devoted to the economics today, commenting on the competitiveness of geothermal, and the investment costs, operation and maintenance costs, production cost and cost of financing.
In the vision the economic perspective and cost reductions are also treated.
Issues related to financing are also discussed.

**Policy**
The actions related to the policy framework are structured by subject: regulatory framework and support incentives, market facilitations and transformation, research, development and demonstration support, **international collaboration** and deployment in developing economies. First the actions, including timeframes and actors which should execute these actions are presented in a table, followed by text in which the actions are explained.

It is however mentioned in the conclusion that the following issues are addressed.

"It describes approaches and specific tasks regarding RDD&D; financing mechanisms; legal and regulatory frameworks; public engagement; and international collaboration."

Public engagement is however not seen anywhere.

### Stakeholders

Many stakeholders were involved in the development of this roadmap. A full list can be found on iea.org. These are stakeholders who provide the author with information and/or comments on the working draft. It seems only a small part of the stakeholders are from companies. Most stakeholders are from the government or (governmental) research institutions.

"Robert Hopkirk (Geothermal Explorers Ltd.) Mike Mongillo (GNS Science) Chris Bromley (GNS Science) Tom Williams (US NREL) Britta Ganz (DE LIAG) Lotha Wissing (DE Forschungszentrum Jülich GmbH) Yoonho Song (KR KIGAM) Ladislaus Rybach (Institute of Geophysics, Zurich) Rick Belt (AU RES); Martin Schöpe (DE BMU); Ullrich Bruchmann (DE BMU); Henriette Schweizerhof (DE BMU); Sanusi Satar (Star Energy); John Gorjup (CA NRCAN); Jay Nathwani (US Department of Energy); Wesly Ureña Vargas (Inter American Development Bank); Jan Diederik van Wees (TNO); Zonghe Pang (Chinese Academy of Sciences); Alison Thompson (Cangea); Gunter Siddiqi (CH BFE); Santo Bains (BP); Roy Baria (EGS Ltd); Roberto Lacal Arantegui (JRC); Lucien Bronicki (Ormat); Ifnaldi Sikumbang (Indonesia Geothermal Association); Aisyah Kusuma (Geodipa); Keith Evans (Geologisches Institut, Zurich); Ruggero Bertani (Enel); Thomas Kölbel (ENBW); Luis Gutiérrez-Negrín (Geotermia); Akihiro Takaki (JP NEDO); Christoph Clauser (EON Energy Research Centre); Margarita de Gregorio (APPA); Laura van der Molen (NL EZ); Victor van Heekeren (Platform Geothermie); Jean-Philippe Gibaud (Schlumberger); Ken Williamson (Consultant); Burkhard Sanner (EGEC); Philippe Dumas (EGEC); Christian Boissavy (EGEC); Miklos Antics (Geoproduction); Herman Darnel (ID National Energy Council); Andreas Indinger (AT, Energy Agency); Andrew Robertson (NZ MED); Sylvia Ramos (Energy Development Corporation/ Philippines National Geothermal Energy Association); Rafael Senga (WWF); Varun Chandrasekhar (GeoSyndicate Power); Suresh V. Garimella (US DOS); Fernando Echavarria (US DOS); Michael Whitfield (AU RET); Eva Schill (University Neufchatel); and Steve Martin (UK DECC)."

### Public

The public of the roadmap consists of policy makers, industry, research institutes and financial institutions.
The stakeholders which are mentioned which should execute the actions are the government, research institutions and/or universities, the geothermal industry, drilling industry, industry related to district heating and hydrocarbon industry, and financial institutions: commercial banks and multi-lateral/bi-lateral development banks.

### Sender

The sender of the roadmap is the IEA.
"The IEA is an autonomous body, which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme."

"The OECD is a unique forum where the governments of 30 countries work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The OE CD provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies."

### Timeframe

The timeframe of the key actions is 10 years. The graphs belonging to the scenarios and the vision span a few decades, from 2010 to 2050. Most of the actions mentioned in the chapters actions and milestones have a timeframe from 2011 to 2020/2025/2040

### Scope

This roadmap has a global scope

### Comments

- It is said that the roadmap should be regarded as work in progress.

"This roadmap should be regarded as work in progress. As global geothermal efforts advance, new data will provide the basis for updated analysis. Moreover, as the technology, market, power sector and regulatory environments continue to evolve, analyses will need to be updated and additional tasks may come to light."

In the conclusion this is mentioned again.

"The IEA, together with government, industry and NGO stakeholders, will report regularly on the progress achieved toward this roadmap's vision."

Title: Canadian Geothermal Heat Pump Industry Technology Roadmap Final Report
Published: 2012
Organization: Canadian GeoExchange Caolition

**Purpose**

The main aim is to set out a more detailed strategy, especially for industry but also for the government.

"Participants agreed that a roadmap would enable the geothermal industry and its stakeholders to reflect on and analyze the events of the last ten years, and allow stakeholders to focus on the state of the industry, measure its progress, and evaluate its capacity while identifying new areas of development."
"This roadmap is an industry-led initiative that has developed a long-term vision for the industry."
"Three essential parts of the roadmap process are: (1) identifying industry priorities; (2) defining the role of the involved stakeholder groups, as well as; (3) how the will collaborate towards achieving a common goal."
"It provide stakeholders with a structured vision of the medium-term goals for industry and identifies specific milestones and recommendations to achieve these goals"
"This roadmap process responds to government, utility, and industry requests for a more detailed strategy regarding the future of the Canadian GHP industry."

It is noticeable that the heat pump technology is not explained. And it is assumed for example that you understand the difference between a ground source heat pump, geothermal power, geothermal heating, or geoexchange.

"Many Canadians do not easily distinguish 'ground source heat pump' from 'geothermal power', 'geothermal heating', or 'geoexchange'."

Therefore this document is not meant to inform for example the public or governments about the technique, or to convince them of the technology.
The only chapter which purpose is possibly to convince the government is section IV, geothermal heat pump technology policy. This is a small chapter in which it is explained why the government should support the development of heatpumps (because of the reduced $CO_2$ emissions).
The importance of heatpumps for example the environment not is discussed in the messages of the roadmap steering committee chair and from the GHG. So the main purpose of this document is not to convince.

"This roadmap is different from past consultations. Roadmap particiopants must be commende for their insights as they went much further than talk about how to address the indstry's "traditional barriers: high first cost, lack of training or lack of information. Roadmap participants discussed and identified clear actions that can be taken by a multitude of stakeholders. They did not create a shopping list aimed at utilities and governments. They suggested things that could be accomplished by the industry itself"

**Methodology**

The methodology/process of this roadmap is explained in detail.


The process consisted of a sequence of workshops. In the first workshop the Steering Committee defined the strategic environment of the geothermal industry in Canada and a general vision, scope and purpose, priorities and timelines for the roadmap. The second workshop was a "scenario planning" or "visioning" workshop. Strategy workshops were held in multiple cities across Canada with CGC members and other industry stakeholders. Purpose of these roadmapping workshops was to develop objectives, strategies, brainstorm on a list of tactics. Working groups were created to review each category, address any additional objectives and strategies, and agree on the strategies and action plans to be carried out by 2020. Other comments, ideas could be submitted through internet.

### Structure

The structure of the document is summarized below. The vision, status now are mentioned very briefly. The focus is on the actions.

**Acknowledgements**
**Steering Committee**
The members of the steering committee are introduced.
**Message from the CGC**
The background of the roadmap and the process is elaborated.
**Message from the Roadmap Steering Committee Chair**
In this message also a bit of background of the roadmap, why the roadmap is made, is explained.
**The Canadian Geothermal Heat Pump Industry Technology Roadmap – *Process Outline***
As already becomes clear from the title, the process is explained in this chapter.
**Canadian Geothermal Heat Pump Industry *The Path Forward***
In this chapter multiple things are told. This message is a bit messy. The growth of the industry and the status is shortly explained. The benefit for society is briefly addressed as well as the role of Canada in the R&D for heat pump systems. Also the workforce needed for the growth of this industry is elaborated. Furthermore the road mapping process is shortly explained, as well as the contents of the roadmap. The topics and the structure of the roadmap is partly explained.
**Section I Technology Development and R&D**
In this chapter issues are addressed and actions are formulated. Each issues is explained though text and the actions follow immediately. This chapter is divided into 1. Technology Improvements, in which the need of R&D for components, design strategy, drilling, groundwater and aquifer protection is addressed. 2. Knowledge Sharing, focuses mainly on the research and the cooperation between institutions, universities and industry.
**Section II Training and Capacity Building**
This chapter has the same structure as the chapter before. Each issue is explained through text and the actions follow. This chapter focuses on training and education, workforces.
**Section III Outreach**
This chapter also has the same structure as the chapters before. Each issue is explained through text and the actions follow. This chapter focuses on 5. Stakeholder engagement and cooperation The cooperation between different parties and also the development of business cases. 6. Marketing, the need to inform customers, and to sell the product.
**Section IV Geothermal Heat Pump Technology Policy**
This seems to be a small chapter on what the government could do to help industry. First it is explained that the policies nowadays are not sufficient. It is explained which programs and policies already exist and what industry needs of the government. It is explained why the government should support heatpump: just as for renewables less $CO_2$ emissions
**Section V Proposed Market Research**
These are the studies which are needed according to participants of the workshop. In many areas, participants felt that the industry needed more information before proceeding with specific strategies or recommendations and suggested market research and analyses.
**Conclusion**
In the conclusion it is told what is done. Also how the project will be continued.

### Topic and themes

Several topics and themes are addressed. Each chapter is devoted to a topic or theme.

- -*R&D* Technology Improvements; R&D for components; design strategy; drilling; groundwater and aquifer protection
- -*Knowledge Sharing* Research and the cooperation between institutions, universities and industry.
- -*Training &education* Mainly focused on universities and workforce, and that stakeholders (like architects)are aware of the technology
- -*Outreach* The cooperation between different parties and also the development of business cases.
- - *Marketing* Inform customers, and to sell the product.
- - *Policy* Convince support is needed, actions

### Stakeholders

There isn't a list of stakeholders given which participated in the workshops or were in the workgroups. The members of the Steering Committee are given.
These stakeholders are mostly manufacturers of heat pumps, system components or refrigerant (9 persons). Two persons are from educational institutions and one person is from the government.

### Public

This roadmap is mainly aimed at industry, but also at the government. This becomes clear from the following sentences from the conclusion. Furthermore the actions mentioned in the appendices are aimed at CGC itself, system designers, private and public labs, utilities, universities, manufacturers, distributors, labs, patent consultants but also federal, provincial and municipal governments.
"This roadmap process responds to government, utility, and industry requests for a more detailed strategy regarding the future of the Canadian GHP industry. "

### Sender

It is said that this roadmap is an industry-led initiative

"This roadmap is an industry-led initiative that has developed a long-term vision for the industry."
The sender of this roadmap is the Canadian GeoExchange Coalition. This is a non-profit, federally incorporated cooperation. The members are mainly companies and utilities.
"The CGC is guided by a vision to transform the heating, ventilation and air conditioning (HVAC) market in Canada by:

- Expanding the market in Canada for geoexchange products and services;
- Facilitating business development in a way that complements the participants' core business;
- Promoting the CGC's contribution to the Canadian economy through increased sales revenues, jobs creation, and enhanced export opportunities; and,
- Improving environmental performance, including the reduction of greenhouse gas emissions."

### Timeframe

The milestones associated to the actions, mentioned in the appendix are short term: from now to 2015.
In the conclusion a timeframe of 7 years is mentioned.

"However, this document is not a finished product, and the roadmap process does not end with its publication. The next seven years will involve CGC's regularly evolving process that takes into account new breakthroughs in research and development, new types of policies and collaborations, and new marketing and awareness-raising programs for customers."

### Scope

The document has a national scope.

### Comments

- This roadmap focuses solely on heat pumps. It does not seem to focus on deep geothermal heat.
- In the appendix the actions are given, including a very detailed timeframe (per quartile) and indication which parties should execute these actions.

| | |
|---|---|
| Title: | Australian Geothermal Industry Technology Roadmap |
| Published: | 2008 |
| Organization: | Australian Government Department of Resources Energy and Tourism |

**Purpose**

This roadmap focuses on technical issues, on research and development needs. So actually it gives a kind of overview of all the needs. The needs are translated into actions and the most important ones are emphasized.

"In 2007 the Council of Australian Governments (COAG) agreed that four technology roadmaps should be developed addressing geothermal, hydrogen, solar thermal and coal gasification. The Australian Government Department of Resources, Energy and Tourism (RET) was responsible for the development of the geothermal technology roadmap and commissioned Sinclair Knight Merz (SKM) to produce this report."
"The Roadmap examines in detail the research and development needs of the geothermal industry in Australia."
Furthermore like almost every other roadmap this roadmap also has the aim to convince:
"Given the need and desire to develop a more secure and sustainable energy sector, the growing Australian geothermal industry has the potential to become a significant future Australian energy provider, particularly in terms of electricity generation."

Another purpose of this roadmap is to inform. The roadmap explains a lot of technical issues, gives a lot of background on the issues. The document is very extensive.

**Methodology**

Not really a vision was defined. The technical needs were identified through workshops. Also actions or recommendations for the timeline were identified through this workshop. No analyses were conducted, no scenario analyses were used.
RET would also like to acknowledge the contributions of the state and territory governments in the preparation of the roadmap, and the individuals and organisations which participated in **preparatory workshops** in Brisbane, Adelaide and Sydney in November and December 2007. Finally, RET would like to thank the members of the **Project Reference Group**, which provided oversight and input to this project:

"The following key recommendations represent findings, established during the industry consultation and workshopping processes, regarding technological advancements that are required in order to maximise the industry's potential for success. These recommendations form the essential core of the Roadmap."
"In the following chart a possible timeline for geothermal development in Australia over the next 6 years is put forward. The timeline also extends back to the start of 2007 to show what has already been achieved. It has been based on discussions as to what is generally considered feasible with the industry."

**Structure**

The structure is summarized below. Also a quote from the roadmap gives insight into the structure. In the chapter purpose and structure the background of the roadmapping project is discussed, followed by the key technological recommendations. Also some technical background information is given regarding the technique and the status today of the technique. Chapter 2-8 technical needs, issues are discussed very extensively. Chapter 9 discusses emerging technologies. A summary of the issues and needs is given in chapter 10 through a table. Also a timeline is included.

"The structure of this document is to first present in Section 2 key technological recommendations. Section 3 includes a summary of geothermal energy development, the issues which potentially affect geothermal development in Australia, and the extent to which those are unique to this country or unique to the geothermal industry generally. Sections 4 to 8 consist of an assessment of the current state of domestic and international geothermal technology, research and infrastructure. It follows a logical sequence through the course of a typical geothermal development, from surface exploration, to drilling and delineation to power plant development along with associated technological issues of an environmental nature. Section 9 covers new and emerging technologies both for power generation and other applications which may be relevant to Australia. Section 10 outlines goals and a timeline for technology research, development and demonstration. Section 11 expands on recommendations for actions arising from Section 10 as determined through the consultation process undertaken, though the practical implications of those in terms of institutional, regulatory and financing matters is addressed separately in the wider-ranging Framework."

**Acknowledgement**

**1. Purpose and structure**

In this chapter a bit of the background of the roadmap, the topics and themes it covers, the purpose and structure of the roadmap are explained.

**2. Key Technological recommendations**

In this chapter the most important findings established during the industry consultation and workshopping processes, which form "the essential core of the roadmap". The chapter is divided in first priority and second priority actions.

**3. Background: Setting the scene**

In this chapter some background information on geothermal energy is given. The history of the use of geothermal energy is discussed, the current status of geothermal development, the types/nature of geothermal resources including the status now for these different resources. Besides the status now worldwide also the status of geothermal energy in Australia is discussed. Especially the exploration is elaborated and the need for cooperation/data availability is explained. The Australian Geothermal Energy group and the costs of energy/geothermal energy generation are discussed.

**4. Issues and Status: Geothermal explorations**

First the steps which need to be taken for geothermal explorations are explained.
The current state of knowledge, and technological and knowledge gaps, are discussed under each of these headings in the following sections: availability of and access to geosciences and associated information; tectonic setting of Australia, geological structure; thermal structure; porosity and permeability; stress regime; emerging technologies; defining "geothermal resources and geothermal reserves.

**5. Issues and Status: Drilling and stimulation technologies**

**6. Issues and Status: Reservoir modeling, assessment and management**

**7. Issues and Status: Power conversion technology**

**8. Issues and Status: Environmental**

**9. Emerging Technologies and New Uses for Geothermal**

In this chapter new technologies and the potential of new technologies is discussed.

**10. Issues, Solutions, Goals and timeline**

This chapter summarizes the document using a table in which the actions, issues, urgency, stakeholders responsible and some other characteristics are summarized. It focuses solely on technical issues. All significant technical challenges are included. Also a possible timeline is made. In this timeline not all actions/needs are included, only the more important ones.

**11. Conclusions and Recommendations**

Conclusive chapter again including first priority and second priority actions

## Topic and themes

This roadmap focuses solely on technical issues. There are however overlaps.

"The Roadmap examines in detail the research and development needs of the geothermal industry in Australia."
"There are overlaps between technological and other constraints on commercial geothermal development that cannot be divorced. Some problems such as the need for development of improved downhole packers and measurement tools are technical constraints that will have to be overcome for the industry to be feasible. Other requirements, such as improving power plant efficiencies, are not absolute technical constraints in a strict sense, but improvements which will change the economic feasibility of projects and have a large impact on what can be considered resources. Other issues are in the proof of concept category: for example, the industry is confident that power can be generated from hot rock (HR) geothermal energy in Australia and in that sense the technical feasibility of power generation is assumed by the developers, but it will have a large impact on the ability to finance projects once a HR demonstration is up and running. In practical terms all of these categories of constraints need technological inputs to address them."
"The Framework examines a broader range of challenges to the commercialisation of geothermal energy in Australia: attracting investment; geoscience; industry networks; international linkages and partnerships; research and development; human capital; community engagement; engagement with energy policy processes; and legislation and regulation."
"In this section of the Roadmap all significant technical challenges and possible solutions are identified regardless of their priority and whether any intervention by government is considered necessary. This is not a table of recommendations. However an indication of which issues are considered the most critical is included. Issues which do not have a technical component are not generally included as they are addressed in the Geothermal Industry Development Framework, though a few related matters such as international technical linkages are touched upon."

### Stakeholders

No list of participating stakeholders is given. Only the members of the Project Reference Group are given.

"RET would also like to acknowledge the contributions of the state and territory governments in the preparation of the roadmap, and the individuals and organisations which participated in preparatory workshops in Brisbane, Adelaide and Sydney in November and December 2007. Finally, RET would like to thank the members of the Project Reference Group, which provided oversight and input to this project:

- Dr Adrian Williams (Geodynamics);
- Australian Government Department of the Environment, Water, Heritage and the Arts;
- Barry Goldstein (Australian Geothermal Energy Group and Primary Industries and Resources South Australia);
- Geoscience Australia;
- Dr John Wright (CSIRO);
- Susan Jeanes (Australian Geothermal Energy Association); and
- Terry Kallis (Petratherm)."

### Public

The public of the roadmap consists of people from companies and institutions which are knowledgeable in the field of geothermal energy.

### Sender

The sender of this roadmap is the Australian government.
Council of Australian Governments (COAG)

"The Council of Australian Governments (COAG) is the peak intergovernmental forum in Australia. The members of COAG are the Prime Minister, State and Territory Premiers and Chief Ministers and the President of the Australian Local Government Association. COAG has a strong record of implementing reforms that have improved the lives of all Australians."

The Australian Government Department of Resources, Energy and Tourism (RET)
Sinclair Knight Merz (SKM)

"Sinclair Knight Merz is a leading projects firm, with global capability in strategic consulting, engineering and project delivery. It operates across Asia Pacific, the Americas, Europe, the Middle East and Africa, deploying some 7,000 people from more than 40 offices. Formed in 1964 in Sydney as a private company, SKM has retained its independence through employee ownership, with fee income now greater than A$1 billion. Our people come from a diverse range of disciplines including engineers, planners, architects, economists, scientists, project managers, technicians and administrative staff. We continually strive to help our people reach their full potential, engaging them in challenging and inspiring projects that shape industries and build nations."

### Timeframe

The timeframe of the table with actions is 6 years, from 2008 to 2013. When the actions have to be implemented is indicated quite detailed: per quartile.
In the following chart a possible timeline for geothermal development in Australia over the next 6 years is put forward. The timeline also extends back to the start of 2007 to show what has already been achieved. It has been based on discussions as to what is generally considered feasible with the industry.

### Scope

This roadmap has a national scope.

### Comments

- the issues are discussed very extensively

Title: Australian Geothermal Industry Development framework
Published: 2008
Organization: Australian Government Department of Resources Energy and Tourism

**Purpose**

The purpose of this document is to address the non-technical issues of geothermal development in Australia. So the goal is to set out a strategy for non-technical issues and challenges.

"Participants agreed to jointly develop a Geothermal Industry Development Framework to identify strategies for the development of Australia's emerging geothermal industry."
"which examines in detail the technology challenges facing the industry."
"The Framework attempts to identify strategies in each of these areas to provide a pathway for development of a geothermal industry in Australia. These recommendations and strategies can be applied by industry, governments and stakeholders to tackle the challenges facing the sector."
"Developed in close consultation with industry, the Geothermal Industry Development Framework (the Framework) identifies the key issues facing the geothermal sector in Australia, and recommends actions to encourage the development of a viable geothermal energy industry in this country."

Furthermore the goal is also a bit to convince the different stakeholders of the potential of geothermal energy. The tone of the text is sometimes very positive regarding geothermal energy. Also the foreword by the minister for resources and energy and the way the vision is communicated contribute to this positive tone.

Vision

"To make a substantial contribution to Australia's long-term energy supply and reduce our national greenhouse gas emissions by developing a sustainable, safe, secure, socially and environmentally responsible geothermal energy industry."

**Methodology**

Input on different subjects such as workforce, legislative and regulatory frameworks, private sector and government finance and community issues were used in developing the roadmap. The whole process can be seen below.

# Appendix B Consultation process and background

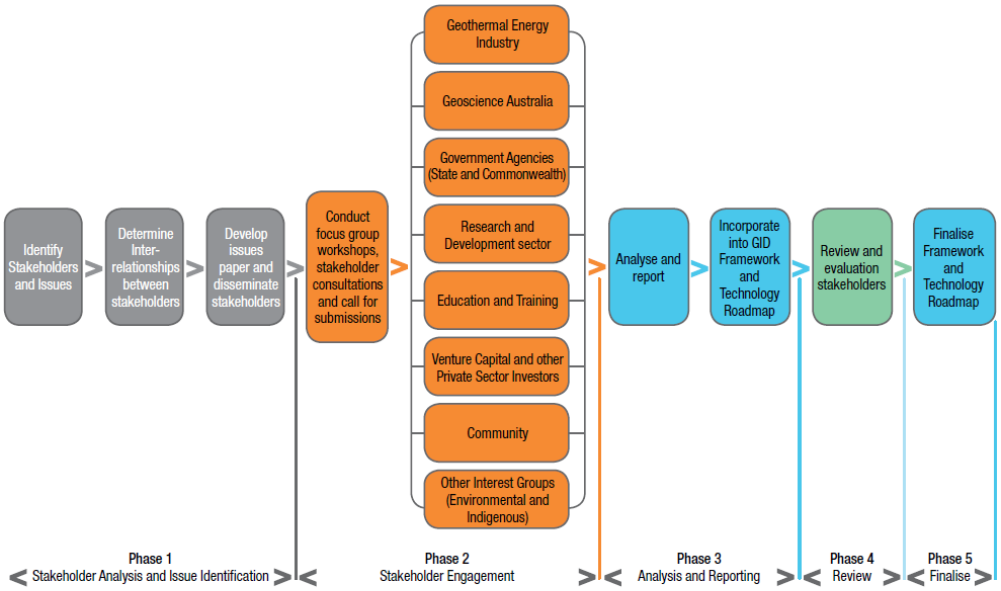
The Geothermal Industry Development Framework has been prepared concurrently alongside the Geothermal Technology Roadmap. The Technology Roadmap was commissioned by the Australian Government on behalf of the Council of Australian Governments (COAG) as one of four technology roadmaps.

Development of the Roadmap and the Framework was managed by the Department of Resources, Energy and Tourism, and steered by a Project Reference Group (PRG) comprising:

- Department of Environment, Water, Heritage and the Arts;
- Geoscience Australia;
- CSIRO;
- Australian Geothermal Energy Association (AGEA),
- Australian Geothermal Energy Group (AGEG),
- Geodynamics Limited; and
- Petratherm Limited.

The process of developing the framework and roadmap began with the drafting of a series of discussion papers. Each paper was followed by a workshop specific to each discussion paper topic, as part of a comprehensive consultation process with the geothermal industry and other stakeholders. This process began in October 2007 and concluded in September 2008.

**Figure 9: Consultation Process Map**




Input was sought from stakeholders through a facilitated consultation process which, together with the workshops, included requests for written submissions and a limited number of face to face interviews.

**Workshops**

A total of five workshops were conducted in November and December 2007, each focusing on a separate theme:

- **Workshop 1 (7 November, Brisbane) – Technology roadmap:** To present the proposed strategy for developing a Geothermal Industry Development Framework and Technology Roadmap and to solicit input from stakeholders on the four key themes outlined in the workshops below.
- **Workshop 2.1 (27 November, Adelaide) – Training and skills development:** To solicit input from stakeholders regarding the research, training and skills development infrastructure required for the geothermal sector.
- **Workshop 2.2 (28 November, Adelaide) - Legislative and regulatory frameworks:** To solicit input from stakeholders regarding the legislative and regulatory framework requirements governing the geothermal sector.
- **Workshop 3.1 (6 December, Sydney) – Private sector and government finance:** To solicit input from stakeholders regarding private sector and government financing structures to support the geothermal sector.
- **Workshop 3.2 (7 December, Sydney) – Community issues:** To solicit input from stakeholders regarding community and environment concerns of the geothermal industry.

**Submissions**

Stakeholders were also provided with an opportunity to make a formal submission to the development framework process via the project website. This provided stakeholders with an avenue to express their views without any constraints provided by the consultation process. A number of submissions were received throughout the consultation period via the web site, and covered key issue areas such as geothermal generation and industry collaboration.

## Structure

**Acknowledgement**

**Foreword minister of resources and energy**

The commitment of the government is expressed. The importance of geothermal energy is expressed (advocate, convince)

**Foreword Australian Geothermal Energy Association**

This foreword is more informative compared to the other foreword

**Contents**

**Vision**

The vision is printed very large in the document. It seems like they want to convince.

**Geothermal industry development framework: Recommendations**

This is a kind of executive summary. The main issues from chapter 1 to 10 are discussed in this chapter

**The potential for geothermal energy in Australia**

Here the potential for geothermal energy in Australia is explained. This chapter is quite positive: objective to convince?

**Scope of the geothermal industry development framework**

Some extra info regarding the pathway is given, the important issues to address and

**1. Overview**

**2. Increasing investment into the geothermal industry**

**3. Geoscientific data**

**4. Industry networks**

**5. International linkages and partnerships**

**6. Research and Development**

**7. Human capital development**

**8. Communication and community consultation**

**9. Understanding the policy environment and contributing to policy development**

**10. Legislation and the regulatory framework**

In these chapters the issues are extensively explained (a lot of text). At the end of each chapter a strategies is proposed.

Chapters 2 to 10 deepen into different subjects. At the end of each chapter a strategy is outlined. There is no conclusion.

## Topic and themes

Several topics and themes are addressed.

- Economy: The chapter increase investment into the geothermal industry is about cost reductions, risks and financial barriers. The costs and the risks should be reduced. Although technical solutions are mentioned, the focus is on economics.
- Data collection: In the chapter geoscientific data is about acquiring and managing geothermal data.
- Networks: Chapter 4 industry networks, for faster learning and to share knowledge. Chapter 8 is about the communications between the different stakeholders.
- International collaboration Chapter 5 is about international collaborations, also to exchange experiences and to promote the expertise of Australia
- R&D Chapter 6 is about R&D
- Workforce Chapter 7 is about the establishment of an industry workforce.
- Outreach and public education Chapter 8 is also about the communication with the public and communities
- Legislation and regulation This topic is treated in chapter 10.

**Stakeholders**

No list of stakeholders, which participated in the workshops, is given. Only the names from the members of the Project Reference group are given. It is said that the roadmap however that it is made in close consultation with industry.

"Developed in close consultation with **industry**, the Geothermal Industry Development Framework (the Framework) identifies the key issues facing the geothermal sector in Australia, and recommends actions to encourage the development of a viable geothermal energy industry in this country."
"The Australian Government Department of Resources, Energy and Tourism (RET) was responsible for the development of this framework. However, many organisations and individuals have contributed to this process and without their input this document could have not been completed. RET would like to thank in particular the members of the Project Reference Group, which was established specifically to guide the development of this framework. The Project Reference Group provided oversight of this project, reviewed many drafts and will now assist RET in the implementation of the recommendations. The Group comprises the following:

- Susan Jeanes (Australian Geothermal Energy Association);
- Terry Kallis (Petratherm);
- Dr Adrian Williams (Geodynamics);
- Dr Barry Goldstein (Australian Geothermal Energy Group);
- Australian Government Department of the Environment, Water, Heritage and the Arts;
- Geoscience Australia; and
- CSIRO."

**Public**

The roadmap is meant for a broad public: industry, governments and other stakeholders.
"These recommendations and strategies can be applied by industry, governments and stakeholders to tackle the challenges facing the sector."

**Sender**

The main sender/initiator is the Australian government. The Australian government has set up this project in which both roadmaps are made. From the quote below however it can be concluded that representatives of companies and research organizations also support this project.

"In 2007, the Australian Government held a roundtable with representatives of companies, government agencies and research organisations with an interest in geothermal energy development. Participants agreed to jointly develop a Geothermal Industry Development Framework to identify strategies for the development of Australia's emerging geothermal industry."

**Timeframe**

There are no timeframes mentioned.

**Scope**

The scope of this roadmap is national.

**Comments**

- In this document there are two forewords. In the technical purpose there are no forewords. Maybe this has to do with the purpose of the document