Final Deliverable
Guidelines for Roadmaps on solar cooling

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IEA Solar Heating and Cooling Program

The Solar Heating and Cooling Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. Its mission is *"to enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050.*

The member countries of the Programme collaborate on projects (referred to as "Tasks") in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

A total of 53 such projects have been initiated to-date, 39 of which have been completed. Research topics include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44)
- Solar Cooling (Tasks 25, 38, 48, 53)
- Solar Heat for Industrial or Agricultural Processes (Tasks 29, 33, 49)
- Solar District Heating (Tasks 7, 45)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52)
- Solar Thermal & PV (Tasks 16, 35)
- Daylighting/Lighting (Tasks 21, 31, 50)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42)

In addition to the project work, there are special activities:

- SHC International Conference on Solar Heating and Cooling for Buildings and Industry
- Solar Heat Worldwide – annual statistics publication
- Memorandum of Understanding with solar thermal trade organizations
- Workshops and conferences

Country Members

Australia	Germany	Singapore
Austria	Finland	South Africa
Belgium	France	Spain
China	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	Turkey
European Commission	Norway	United Kingdom
	Portugal	United States

Sponsor Members

European Copper Institute	Gulf Organization for Research and Development
ECREEE	RCREEE

Current Tasks & Working Group:

Task 42	*Compact Thermal Energy Storage*
Task 43	*Solar Rating and Certification Procedures*
Task 45	*Large Systems: Solar Heating/Cooling Systems, Seasonal Storages, Heat Pumps*
Task 46	*Solar Resource Assessment and Forecasting*
Task 47	*Renovation of Non-Residential Buildings Towards Sustainable Standards*
Task 48	*Quality Assurance and Support Measures for Solar Cooling*
Task 49	*Solar Process Heat for Production and Advanced Applications*
Task 50	*Advanced Lighting Solutions for Retrofitting Buildings*
Task 51	*Solar Energy in Urban Planning*
Task 52	*Solar Energy and Energy Economics in Urban Environments*
Task 53	*New Generation Solar Cooling and Heating (PV or Solar Thermally Driven Systems)*
Task 54	*Price Reduction of Solar Thermal Systems*

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advanced Solar Low Energy Buildings*
Task 14	*Advanced Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 22	*Building Energy Analysis Tools*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*
Task 27	*Performance of Solar Facade Components*
Task 28	*Solar Sustainable Housing*
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*
Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*
Task 34	*Testing and Validation of Building Energy Simulation Tools*
Task 35	*PV/Thermal Solar Systems*
Task 36	*Solar Resource Knowledge Management*
Task 37	*Advanced Housing Renovation with Solar & Conservation*
Task 38	*Solar Thermal Cooling and Air Conditioning*
Task 39	*Polymeric Materials for Solar Thermal Applications*
Task 40	*Towards Net Zero Energy Solar Buildings*
Task 41	*Solar Energy and Architecture*
Task 44	*Solar and Heat Pump Systems*

Completed Working Groups:

CSHPSS; ISOLDE; Materials in Solar Thermal Collectors; Evaluation of Task 13 Houses; Daylight Research

Contents

1 Executive Summary

The work in this subtask D covers horizontal activities related to subtasks A, B, and C. The objectives of this subtask are the implementation of targeted promotion activities based on the collective work results; production of dissemination material for external communication; the implementation of knowledge transfer measures towards the technical stakeholders; the development of instruments and their provision for policy makers and the creation and promotion of certification and standardisation schemes.

Subtask D is structured as follows:

- D1: Web site
- D2: Best Practices brochure
- D3: Simplified short brochure
- D4: Guidelines for Roadmaps on Solar cooling
- D5: Updated specific training seminars adapted to the Quality procedure
- D6: Outreach report

This report is addressed to the results of D4 “Guidelines for Roadmaps on Solar cooling”.

1.1 Structure

Finally the D4 activity focuses on roadmapping process and benefits strongly from the published ‘Energy Technology Roadmaps a guide to development and implementation’ [IEA Guide] of International Energy Agency in 2014. Giving advice for developing roadmap focussing only on solar thermal cooling technology would not lead to the entire picture while the most roadmaps identified address all other promising application of solar heat. The authors of D4 report structured the document as follows.

CHAPTER 2 – Review process

- This chapter is a result of the screening process of existing roadmaps for solar heat technologies. Seven roadmaps from different countries have be identified and taken for analysis with respect to the applied methodology and topics. Furthermore there is information about renewable energy and other policy incentive schemes. A study from United Nations Environment Programme (UNEP) defines five categories and the 20 policy instruments and assess qualitative their relative technical and cost effectiveness and comments on limitations, strengths and special cases.

CHAPTER 3 – Guideline for Roadmapping

- The guideline of roadmapping is strongly based on the published a new edition on ‘Energy Technology Roadmaps a guide to development and implementation [IEA Guide]. This guide is taken as a useful source to elaborate a guide for SHC Technology roadmaps in the framework of SHC Task48. This guideline addresses four different phases for developing a roadmap; i.e. a) Planning and preparation, b) Visioning and target definition phase, c) Roadmap development and d) Roadmap implementation and adjustment. All four phase are briefly described and additionally selected examples from three different existing roadmaps are presented.

1.2 Activities

- Review of existing roadmaps on Solar Thermal technology with focus on methodology and approach
- Update with activity results of subtask C
- Review of the impact of existing incentive schemes (link to C1) focusing on the efficiency of the schemes for the development of the local market (increase of turnover, improvement on quality of installations, ..).
- Setting up guidelines which include proposals for the roadmapping process and to give advice and recommendation by selected good examples.

1.3 Participants

During the course of SHC TASK 48 Expert meetings, the following companies/institutions did contribute on creating this guideline for roadmapping the solar heating and cooling technology:

Table 1: Participating entities

Entities	Person in charge	Country	Contribution
AIT	Anita Preisler*	Austria	Activity Leader
AIT	Tim Selke	Austria	Activity Leader
Green Chiller	Uli Jakob	Germany	Activity contributor
TECSOL	Daniel Mungier	France	Activity contributor
CSIRO	Stephen White	Australia	Contribution with national roadmaps
POLIMI	Marco Calderoni	Italy	Contribution with national roadmaps

*) till May 2014

2 Review process

2.1 Screening of existing roadmaps on Solar Thermal technology

Following abstract on **methodology** and **approach** of listed existing roadmaps and roadmap initiatives (see Annex 1) have been carried out:

- International Roadmap (IEA)
- European Roadmap (ESTTP)
- National Roadmap (Austria)
- National Roadmap (Germany)
- National Roadmap (France)
- National Roadmap (USA)
- Paper SHC 2013 Conference (China)

The filled in abstracts are shown in Annex 2.

2.2 Results of the impact review of existing incentive schemes

Analysis of the 65 incentive measures identified during this exercise lead to the key findings that:

- There is a dominance of direct financial incentives in the responses received. There is a lack of stamp of quality and information provision incentives as well as non-technical and non-financial measures
- It is desirable that implementing levels of Government cooperate with each other to minimise administrative burden, promote consistency and reduce exposure to the winds of political change
- More clarity as to the development requirements of the solar cooling industry is required
- A common format for incentive comparison is desirable – the template provided is suggested with the addition of public and educational buildings as an application niche
- Objective reviews of incentive effectiveness are required by both policymakers and industry

Numerous renewable energy and other policy incentive schemes exist around the world. These have been summarized in a recent the United Nations Environment Programme (UNEP) study which defined and categorized 20 policy instruments in five categories with wide relevance across the Environment field [UNEP]. These five categories and the 20 policy instruments selected by UNEP are shown below in Table 2.

Table 2: Policy instruments analysed in the UNEP Assessment of Policy Instruments for Reducing Greenhouse Gas Emissions From Buildings – Summary and Recommendations report [UNEP]

Control and regulatory instruments		***Economic and market-based instruments***	***Fiscal instruments and incentives***	***Support, information and voluntary action***
Normative: – Appliance standards – Building codes – Procure-ment regulations – Energy efficiency obligations and quotas	Informative: – Mandatory audits – Utility De-mand-side manage-ment (DSM) programs – Mandatory labelling and certifica-tion programs	– Energy performance contracting – Cooperative procurement – Energy efficiency certificate schemes – Kyoto Proto-col flexible mechanisms	– Taxes – Tax ex-emptions / reductions – Public benefit charges – Capital subsidies, grants, subsidized loans	– Voluntary certification and labelling – Voluntary and negotiated agreements – Public leade-ship programs – Awareness raising, education, information campaigns – Detailed billing and disclosure programs

Table 3: Instruments compared in the UNEP report along with their relative technical and cost effectiveness and comments on limitations, strengths and special cases [UNEP]

Policy instrument	***Emission Reduction Effectiveness***	***Cost-effectiveness (a)***	***Special conditions for success, major strengths and limitations, co-benefits***
Appliance standards	High	High	Factors for success: periodical update of standards, inde-pendent control, information, communication, education
Building codes	High	Medium	No incentive to improve beyond target. Only effective if enforced
Public leadership programs, incl. procurement regulations	Medium/High	High/Medium	Can be effectively used to demonstrate new technologies and practices. Mandatory programs have higher potential than voluntary ones. Factors for success: ambitious energy efficiency labeling and testing.
Energy efficiency obligations and quotas	High	High	Continuous improvements necessary: new energy efficiency measures, short term incentives to transform markets
Mandatory audit requirement	High, but variable	Medium	Most effective if combined with other measures such as financial incentives
Demand-side management programs (DSM)	High	High	Tend to be more cost-effective for the commercial sector than for residences.
Energy performance contrac-ting (EPC)/ESCO support (b)	High	Medium	Strength: no need for public spending or market intervention, co-benefit of improved competitiveness.
Cooperative procurement	High	Medium/High	Combination with standards and labeling, choice of products with technical and market potential
Energy efficiency certificate schemes/white certificates	Medium	High/Medium	No long-term experience. Transaction costs can be high. Institutional structures needed. Profound interactions with existing policies. Benefits for employment.

Kyoto Protocol flexible mechanisms (c)	Low	Low	So far limited number of CDM &JI projects in buildings
Taxation (on CO2 or fuels)	Low	Low	Effect depends on price elasticity. Revenues can be earmarked for further efficiency. More effective when combined with other tools.
Tax exemptions/ reductions	High	High	If properly structured, stimulate introduction of highly efficient equipment and new buildings.
Public benefit charges	Medium	High	Success factors: independent administration of funds, regular monitoring &feedback, simple &clear design.
Capital subsidies, grants, subsidized loans	High	Low	Positive for low-income households, risk of free-riders, may induce pioneering investments.
Labelling and certification programs	Medium/High	High	Mandatory programs more effective than voluntary ones. Effectiveness can be boosted by combination with other instrument and regular updates.
Voluntary and negotiated agreements	Medium / High	Medium	Can be effective when regulations are difficult to enforce, combined with financial incentives, and threat of regulation
Education and information programs	Low / Medium	Medium/High	More applicable in residential sector than commercial. Success condition: best applied in combination with other measures.
Detailed billing and disclosure programs	Medium	Medium	Success conditions: combination with other measures and periodic evaluation.

(a) Cost-effectiveness is related to specific societal cost per carbon emissions avoided. (b) Energy service companies (c) Joint Implementation, Clean Development Mechanism, International Emissions Trading (includes the Green Investment Scheme)

The effectiveness of the selected instruments in reducing GHG emissions, achieving cost-effectiveness for society and other key success factors were used by UNEP as assessment criteria. In analysing the 20 policy instruments selected, UNEP found that many policy instruments evaluated were able to achieve high savings at low or even negative costs for society. Despite this, the technical (emissions reduction) potential and economic (cost effectiveness) potential varied significantly over the instruments analysed. Moreover, many instruments carried significant special conditions and constraints as can be seen in the analysis summary's rightmost column in Table 3.

2.3 Evaluation Matrix

The content of the filled in abstracts about existing roadmaps was then used for the evaluation matrix to compare the used approaches, methodologies and addressed topics (see Annex 3).
The evaluation of used methodologies in Figure 1 shows historical investigation and cost analyses were used in all analysed existing roadmaps, then statistics and market analyses follow in the quantity. The actual contact with experts in workshops interviews or by SWOT analyses was used in four of the seven existing roadmaps. Analyses of energy saving potentials and simulations were only used once in the existing roadmaps.

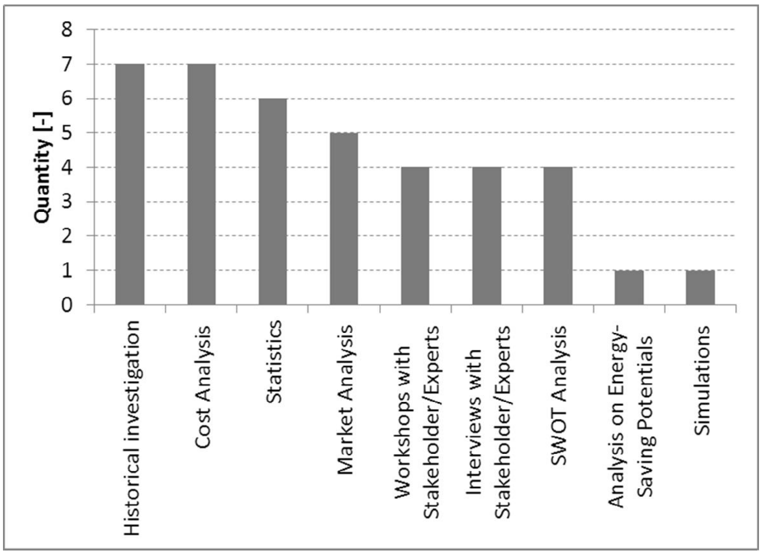

Figure 1: Methodologies used in analyzed existing roadmaps on solar heating and cooling (AIT)

The difference between the addressed topics in the analyzed existing roadmaps was not significant (see Figure 2). The initial situation, market penetration and costs were addressed in all of the analyzed existing roadmaps. Technology development, cost development, customer groups, high potential applications and sales volume was addressed in most of the analyzed existing roadmaps. Incentive schemes and quality assurance were only addressed in the minority of the analyzed existing roadmaps.

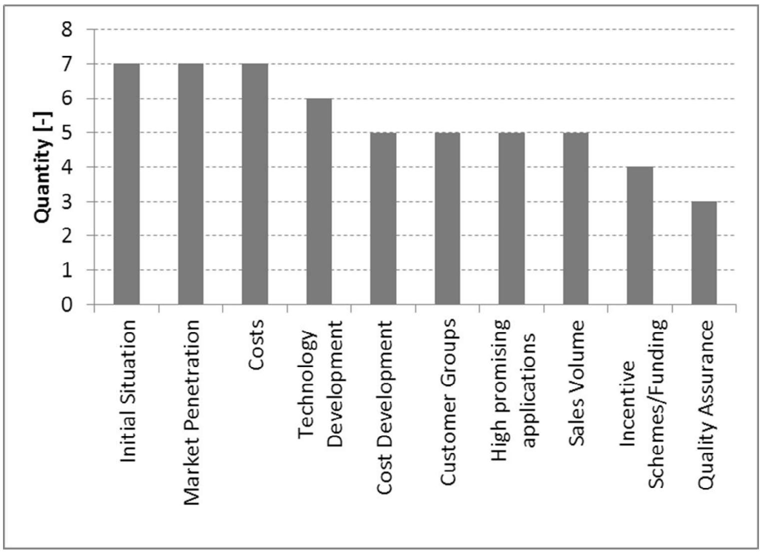

Figure 2: Main topics addressed in analyzed existing roadmaps on solar heating and cooling (AIT)

3 Guideline for Roadmapping

2014 the International Energy Agency published a new edition on Energy Technology Roadmaps a guide to development and implementation [IEA Guide]. This guide is a useful source to elaborate a guide for SHC Technology roadmaps in the framework of SHC TASK48. Furthermore by D4 activities a screening process of relevant material and some interviews with selected roadmap creators have been conducted.

Generally speaking there is no right way to develop a roadmap and the process itself is key. 'Some processes engage large groups of stakeholders who spend long periods gathering many diverse contributions and building consensus on priorities. Others are developed by a small group of knowledgeable analysts and experts who work intensively for a short period to integrate available data, analysis and insights into a logical framework. Each approach has its merits, and the organisation or community responsible for developing the roadmap must determine which one works best for its situation.'

Considering these different sources of information the D4 activity group of SHC TASK48 tried to condense the key findings and lessons learnt for developing a roadmap for solar cooling. Specifically there is a focus on describing the roadmap process in general and to display some good examples from existing roadmaps for solar heating and cooling. This guideline addresses four different phases for developing a roadmap, which is proposed by the IEA 'Energy Technology Roadmaps a guide to development and implementation' [IEA Guide]:

a) Planning and preparation
b) Visioning and target definition phase
c) Roadmap development
d) Roadmap implementation and adjustment

All four different phase are briefly described and in each phase the applied methods and its exemplary case from existing roadmaps are presented. The selected exemplary representing cases are taken from three different existing roadmap documents. These are:

- International Energy Agency (IEA) Technology Roadmap, Solar Heating and Cooling [IEA R SHC]
- ESTTP Solar Heating and Cooling for a Sustainable Energy Future in Europe 2012 [ESTTP R SHC]
- Austrian Roadmap 'Solar Heat 2025' A technology and market analysis with recommendation for actions [AUS R SH]

The authors are aware that each technology roadmap is a specific product of individuals and different countries do have different challenges to tackle with. Nevertheless setting up a guideline with a focus on applied and successful methods create an added value to the SHC members and observers. This guideline doesn't claim for completeness.

3.1 Why technology roadmaps?

In general technology roadmaps help to (no claim to completeness):

- Enable governments, industry and financial partners to make the right choices

- Societies make the right decisions in seeking to transition to a low-carbon future
- Set priorities highest-impact actions in the near term while laying the groundwork for longer-term improvements. This helps to avoid misleading decisions for mid- and long-term technology developments
- Identifying and addressing technology-specific barriers
- Highlighting necessary deployment policies and incentives
- Directing increased RD&D funding for new technologies
- Supporting technology diffusion in all major economies
- Team-up relevant stakeholders and bring together different perspectives and interests

SHC Technology roadmaps address key questions (no claim to completeness):

- Where to invest effectively in order to contribute to climate and energy targets because the next decades are key?
- What technological potential is indicated for what kind of SHC technology?
- What regulatory framework sets the direction of effective implementation?
- What are the economic opportunities for different industry sectors?
- What Industrial Initiatives lead to turn the opportunity into reality?

3.2 General Lessons Learned and Recommendation

During the screening process of existing roadmaps for SHC, some additional interviews with roadmap creators were conducted and the public material from the IEA Expert Group of Roadmap Development was analysed. Considering these different resources of information some general findings and lessons learned can be stated:

- Successful roadmap contains a clear statement of the desired outcome followed by a specific pathway for reaching it.
- Challenging is setting up long-term target and attract the market and industry by short-term benefits
- Bring together the right SHC community (Research, Market Actors, Industry and Politics) and let them actively contribute.
- Nominate one powerful innovation agent; it could be a person or an association from research centre or industry. This helps to actively to bring forward the entire process and tracking it.
- Identify barriers –technical, regulatory, policy, financial, public acceptance
- Consider and analyse competing technology development and innovation steps as well
- Setting up action plans for implementation and propose action items for each stakeholder
- Consider the roadmapping process as an vital and organic process which needs to be updated frequently in order to reflect the entire progress and changes.

3.3 Road mapping process in four phases

A comprehensive roadmap process outline is documented and displayed in the guide of Energy Technology Roadmaps from the International Energy Agency. There is highlighted by the experts that the process contains two types of activities a) expert judgement and consensus and b) data and analysis. In addition to the international guide this D4 report of SHC TASK48 is addressing and highlighting some examples from the screened roadmaps for each indicated process phase. Typically there are examples taken from one International, European and National road per process phase.

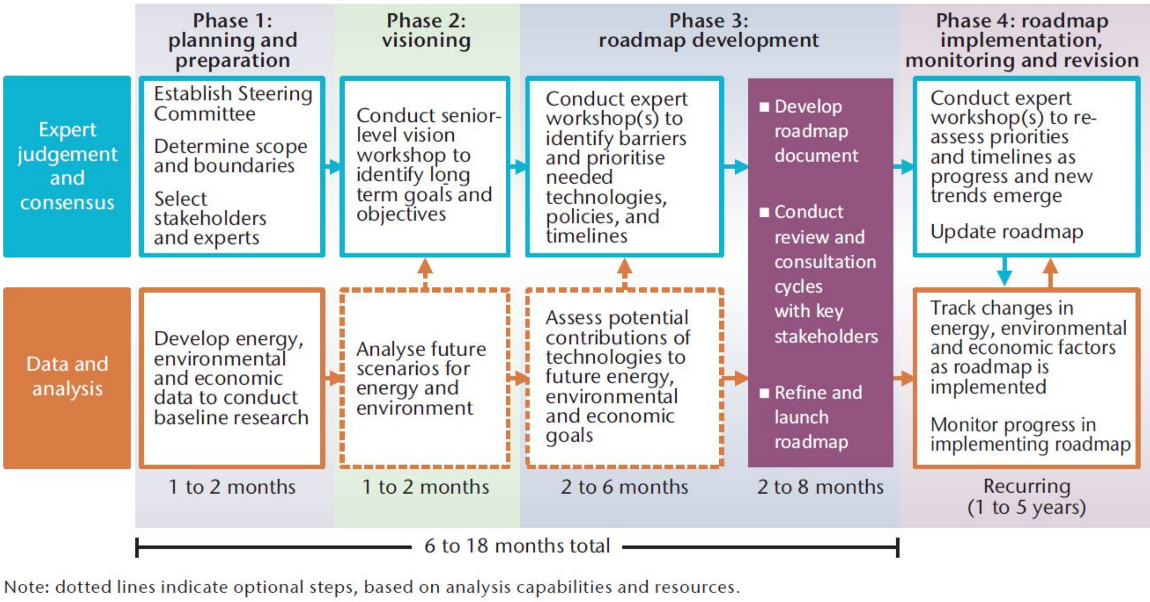

Figure 3: Roadmap process outline (Source: IEA ETR page 6)

3.4 Definition of terms

This part is directly taken from the IEA document [IEA Guide]:

- **'Roadmap**: a specialised type of strategic plan that outlines activities an organisation can undertake over specified time frames to achieve stated goals and outcomes.
- **Roadmapping**: the evolving process by which a roadmap is created, implemented, monitored and updated as necessary.
- **Setting a vision**: the process of analysing future scenarios and identifying objectives.
- **Stakeholders**: relevant individuals who have an interest in seeing the roadmap developed and implemented, such as representatives from industry, government, academia and non-governmental organisations (NGOs).
- **Implementation**: the process of putting a roadmap into action, by carrying out projects and initiatives that address roadmap tasks and priorities, and by monitoring progress using a tracking system.'

3.4.1 Phase 1: Planning and Preparation activities

According to the IEA Guide in the planning and preparation phase, the organisation undertaking the roadmapping initiative needs to answer key questions like:

- Which technology areas or classes will the roadmap consider? Which energy sources or end-use sectors will be considered?
- What is the time frame for the roadmapping effort? Is the roadmap a 5-year plan, a 20-year plan or a 50-year plan?
- What is the current state of the technology under consideration (current installed base, potential energy savings, cost, efficiency, etc.)?

- How will the organisation conducting the roadmapping effort implement and use the resulting roadmap?
- Will the roadmap be used primarily to guide national government decision making?
- Will the roadmap need to engage the private sector to achieve the stated goals?
- What existing tools or analysis, such as other roadmaps, can be used to influence scoping decisions?

The SHC Task48 D4 activity group additionally identified other advices in order to plan and prepare the activities for roadmapping:

- Find an agreement which SHC topic the roadmap is focusing on and which topics the roadmap does not contain (shall the roadmap give detailed information about a technology and progresses or shall it emphasise on economic analysis, on application analysis, ?)
- Conduct baseline research for technology, markets and public policy. Analyse important sources of information (books, reports, investigations, R&D activities …) and for experts on the subject area and other key stakeholders.
- Bring together the Community (Research, Market Actors, Industry and Politics) and let them actively contribute. Design together a plan for the further procedure
  - What are the key points of the roadmap, make a time plan for the progress of the map,
  - What are critical points of the map and how can they be overcome
  - Which topics take the most time to work on, …)
  - What are the resources?
- Essential seems the nomination of one powerful innovation agent, it could be a person or an association from research centre or industry. This helps to actively bring forward the entire process and tracking it. With this regard the appointment of a steering committee helps to make decisions on goals, scope and boundaries.

Here some selected examples for involvements of the community during the SHC roadmapping process:

- In *the International Roadmap* [[IEA R SHC] all roadmap members are listed in the chapter acknowledgements (page 4), many research centres as well as universities and ministries for environment or similar of different countries have contributed.
- The *European Roadmap* [ESTTP R SHC] was developed by the European Solar Thermal Technology Platform (ESTTP) in cooperation with about 100 experts in the field of solar thermal research and applications.
- The *Austrian roadmap on solar thermal technology* [AUS R SH]was mandated by the federal ministries (Austrian Ministry for Transport, Innovation and Technology, The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management and Federal Ministry of Science, Research and Economy) and the Austria Solar Association. The roadmap is a result of a close cooperation and intensive exchange with the Austrian solar thermal industry and a variety of other important stakeholders. A broad consensus between Solar thermal industry and competent departments in three ministries has been achieved. Three key questions of main importance to Austrians solar thermal companies have been addressed:
  - How can the mentioned market decline turned into a stable market growth again (time frame 2013 to 2025 and further to 2050)?
  - What are practicable actions to make this turnaround and which groups of stakeholders are affected?

- What is the contribution of solar heat in a sustainable energy supply system or in a “Low-Carbon-Economy” in Austria (till 2025 and further to 2050)?”

An activity of the planning and preparation phase is the conduction of baseline research related to energy, environmental and economic data and its analysis. Herewith the SHC Task48 D4 activity group additionally highlights some action and advices some investigations:

- Generally document on the current status of SHC systems related to technology, markets and public policy. Further information to this are available in IEA Guide [IEA Guide] - see page 10 and 11.
- Investigate the actual state of science, technology and market of SHC systems, consider as well competing innovative technologies like actually PV driven compression chillers, heat pump systems and address the success of these kind of technology combination.
- Indicate the technological progress that has been achieved in the last decades
- Specify the investment and operating costs and provide an insight into economic aspects (depending on the topic of the roadmap, but a brief overview should exist in every roadmap)
- Display an overview of the national and worldwide deployment of technology
- Show up the competence in the country, indicate group of experts, competence centres, companies etc. and the SHC system community – with inner critical mass

With regard to market deployment of some SHC systems and technologies examples from selected International, European and national roadmaps are quoted here:

- The introduction of the International Roadmap [IEA R SHC] contains:
  - “Solar heat can be captured by a variety of technologies and utilised in a wide number of applications. The most mature technology, the solar domestic hot water system, has a long history but was first deployed on a large scale in the 1960s in countries such as Australia, Japan and Israel (IEA, 2011a). Since then some markets have shown strong increased deployment as a result of the introduction of long-term subsidy schemes or solar obligations (e.g. subsidies in Austria and Germany, and solar obligations in Israel) or as a result of solar hot water systems’ competitive advantages over alternative technologies (e.g. Cyprus). Over the past 15 years, China’s economic development has spurred the market for solar hot water heating in terms of both system component manufacture and end-use demand.” (*p. 10)*
  - “By the end of 2010, the solar thermal collector capacity in operation worldwide equaled 195.8 GWth, corresponding to 279.7 million square meters; by the end of 2011 it was estimated to have grown by 25%, to 245 GWth (Weiss and Mauthner, 2012). Of this, 88.3% comprised flat-plate collectors (FPC) and evacuated tube collectors (ETC), 11% unglazed water collectors and 0.7% glazed and unglazed air collectors.” (*p. 10)*

- In chapter ‘The Unique Benefits of Solar Thermal’ (comparable to introduction) of the European Roadmap [ESTTP R SHC] is written:
  - “Certainly, the use of biomass and heat pumps will rise significantly. However, scarce biomass resources are needed to fulfill the demand from other energy and non-energy fields, while a wide deployment of heat pumps as a main source of heating would imply a massive increase in electricity consumption, with strong economic and environmental external costs. Therefore, solar thermal (ST) will become an indispensable and crucial pillar of the future energy mix for heating and cooling.” (p.15)

  - "ST is becoming more and more popular in a growing number of countries worldwide. The worldwide market for ST systems has been growing continuously since the beginning of the 1990s. In Europe, the market size nearly tripled between 2002 and 2006. Even in the leading European ST markets Austria, Greece and Germany, only a minor part of the residential homes are using ST. In Germany, about 5% of one and two family homes are using ST energy." (p.18)

- In the summary of the Austrian roadmap for solar heat [AUS R SH] is written
  - "Besides other decentralized renewable energy sources (photovoltaics, ambient heat, biomass) solar heat can contribute an important input to a sustainable energy system. Although that electricity production accounts only for 20% of Austrians final energy consumption electric power generation stands foreground in political as well as in public discussions. This share is comparatively a small part according to the rest. The major part of the final energy consumption remains to heat with a fraction of 46% in 2011; particularly the low-temperature heat consumption at temperature levels below 250°C." (p.10)
  - "By the end of the year 2011 335.1 Million m² collector capacity were installed which corresponds to a thermal power of 234.6 GWth. The worldwide absolutely largest installed capacity of flat plate collectors and evacuated tube collectors can be found in China (152.2 GWth), Germany (10.7 GWth) and Turkey (10.2 GWth) by the end of the year 2011. In comparison Austria achieved an installed collector capacity of around 3.3 GWth which refers to the eight place. The highest market penetration referring to the solar thermal power per inhabitants can be found in Cyprus with 541.2 kWth and in Israel with 396.6 kWth. Directly followed by Austria on the third place with 355.7 kWth per 1,000 inhabitants." (p.10)
  - "This success story of solar thermal energy use in Austria has led to an excellent international position of Austrian companies demonstrated by an export rate of 81% of totally produced collectors (1.14 Mio. m²) in the year 2012. […]Despite the potentials and the very successful years for Austrian's solar thermal industry (particularly the years between 1990 and 2008) the average yearly market volume for new installations in Europe (EU-27) and also in Austria shrank during the last four years. While the average worldwide market growth rate amounted by approx. 20%. The reduced installation rate refers by main parts to the economy crisis and the photovoltaic-hype." (p.10)

3.4.2 Phase 2: Visioning and target definition

In phase two setting a vision and defining target of the desired pathway for a technology's deployment is key. This part of the roadmapping process includes modelling and scenario analysis, which are important tools used to define possible future states. Further documentation and description of the visioning phase can be found in IEA Guide [IEA Guide]. Successful roadmapping processes often include a vision workshop where leading experts meet to discuss and ultimately define by consensus the desired future state of the nation, sector or organisation under consideration.

What is challenging highly to harmonise long term objectives of the society and politics with short term interests of the industry and other market actors. For that reason some key questions should guide to set up the visions and the target of the SHC Technology roadmap:

- What essential trends of the economy, society are key?

- What vision timespan is foreseen a short, middle or long-term, e.g. 2020 2030 or 2050?
- What specific target do you address?
  - A carbon free energy delivering system?
  - Nearly Zero Energy / Emission Buildings?
  - Support innovation processes?
  - Strengthen R&D/ Economy / Industry?
  - An independency from fossil energy imports?
  - Contributing to national climate and energy targets?

In this context the ‚Energy Technology Perspectives 2010' [ETP2010] of the International Energy Agency indicates what technologies will significantly contribute to the transformation into a secure and low-carbon energy system. This helps to understand the estimated and foreseen contribution of renewable energy technologies for reducing CO2-emissions. In two scenarios possible global developments have been elaborated. This was on one hand a development without changing conditions (Baseline Scenario) and on the other hand, the objective is to reduce greenhouse gas emissions by 2050 to half (BLUE Map Scenario), followed. Within the second BLUE Map Scenario sub-scenarios have been developed which addresses in greater detail the possible potential of specific areas. To reduce the climate impact of the most cost-effective technologies were considered. Figure 4 quantifies the possible impact of key technologies for reducing CO2 emissions under the BLUE Map scenario [ETP2010].

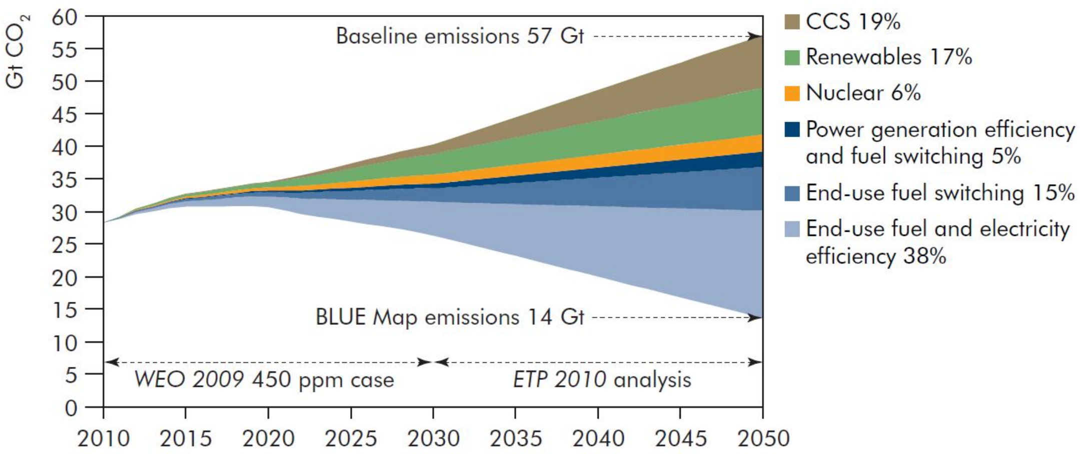

Figure 4: Key technologies for reducing CO2 emissions under the BLUE Map scenario (Source: ETP2010 page 47)

With regard to roadmap visioning and market deployment of some SHC technologies examples from selected International, European and national roadmaps are quoted here:

- The *Technology Roadmap Solar Heating and Cooling of the International Energy Agency* quantifies energy future targets for solar heating and cooling till 2050. The international energy targets of SHC Systems are distributed to two sectors building and industrial.
  - Building sector: solar hot water, space heating and solar cooling
  - Industrial sector: process heat (Low Tem
  - Solar heating and cooling perspectives in China listed separately

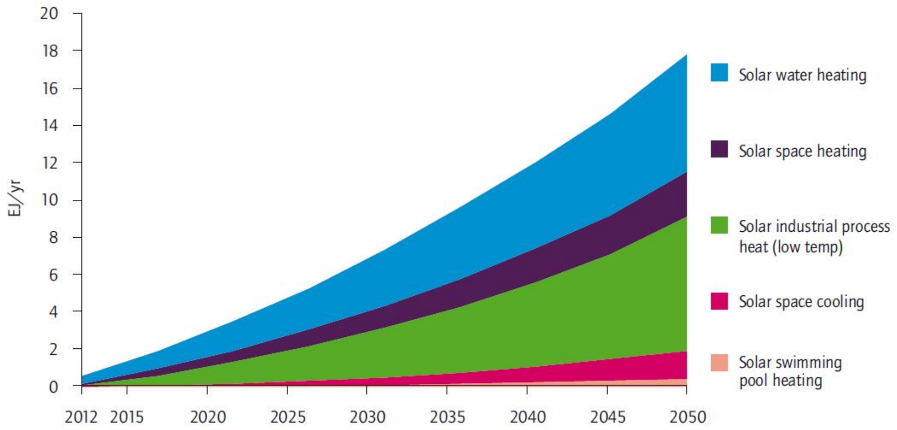

Figure 5*: Roadmap vision for solar heating and cooling (Exajoule/yr) (Source IEA SHC technology roadmap page 22)*

- The European Solar Thermal Technology Platform ESTTP published a document with the title *'Solar Heating and Cooling for a Sustainable Energy Future in Europe'*. In this strategic document from ESTTP three different scenarios have been investigated. Energy targets are described as short-term and long-term targets and are divided into three scenarios: full R&D and policy scenario, advanced market deployment, business as usual), benefits are described separately and are structured in areas of profit (macro-economic benefits, cost competitiveness, employment, international competition and technological leadership). By overcoming a series of technological barriers, it will be possible to achieve a wide market introduction at competitive costs of advanced ST applications like:
    - Solar Active Building, covering at least 100% of their thermal energy with solar, and in some cases providing heat to neighbours
    - High solar fraction space heating for building renovations
    - Wide use of solar for space cooling
    - Wide use of solar for heat intensive services and industrial process heat, including desalination and water treatment

Figure *6* shows how this target of 50% compares to the total heat demand. First the energy demand can be reduced by 40% and from this reduced demand solar can contribute 50% in the long run (around 2050). The division over the application sector is included.

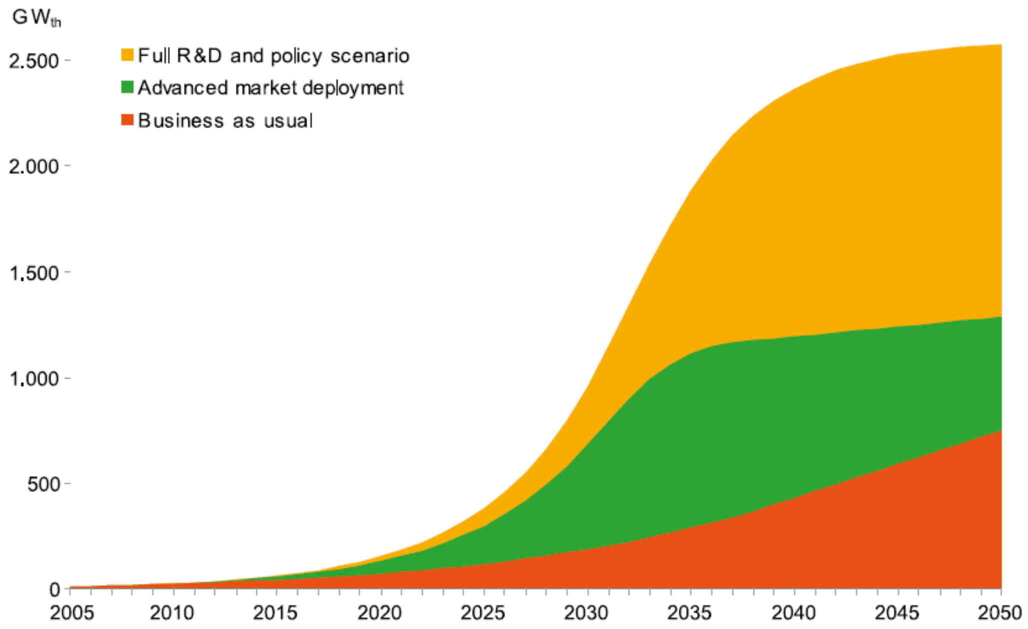

Figure 6: Growth in solar thermal energy use in different scenarios (Source: ESTIF, 2008)

- The *Austrian Roadmap 'Solarwärme 2025'* considers three different scenarios (business as usual, forced activities, ambitioned activities) to be able to give a better overview of what happens if the measures aren't applied and if they are applied, the benefits are clearer and can be seen immediately. Based on a detailed market analysis and several discussions with members of the Austrian solar thermal industry, other important stakeholders from the energy sector, three possible scenarios were developed. The three scenarios differ in the certain intensity of activities and the development of external factors:
- Scenario "Business as usual" (BAU)

This scenario keeps the previous methods, models, instruments and intensity of activities without achievement of relevant technical developments and without cost reduction for the end user. The market gets reduced and remains mainly on private single- and multifamily houses.

- Scenario "Forced activities"

Compared to the BAU scenario this scenario has definitely increased activities on different levels (industry, public authority, research & development) directed to the actual requirements of the technology. Relevant technical developments increase competitive ability with other heat supply technology's and different target groups (small systems in the private sector as well as commercial large systems) and can be attracted by adjusted activities (business models, market launch programs, etc.).

- Scenario "Ambitious activities"

Compared to the scenario "Forced activities", this scenario assumes increased activities on all levels and supports the solar thermal industry along all applications. Besides successful technical developments (cost reduction more than 60% for small systems and 40% for larger systems; seasonal thermal storage with high energy density are available at a market competitive price; solar thermal heat is an integral part of multifunctional building parts and facades, etc.) new business models are investigated and supported by an ambitious revised Austrian energy strategy.

Figure *7* displays in three scenarios the development of the solar thermal technology in terms of collector area, solar heat produced, CO2-reduction, sales volume and jobs.

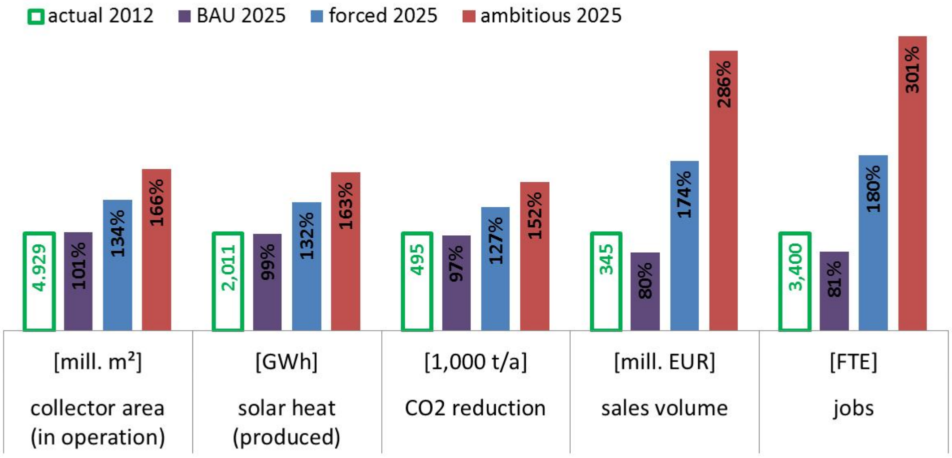

Figure 7: Overview of collector capacity in operation, produced solar heat, CO2-reduction, sales volume and jobs (full time equivalents, FTE) in three scenarios (data based on Biermayer et al., 2013; with own calculations)

3.4.3 Phase 3: Roadmap development

Phase three is dedicated to process for the development of the roadmap. The vision is now established and key is to define activities, priorities and timelines to reach the desired vision. The IEA Guide [IEA Guide] proposes to act with roadmap workshops with a professional workshop preparation and participation of relevant stakeholders. Generally this phase addresses three key activities:

- Hold a roadmap workshop or workshops
- Prepare the draft roadmap document
- Conduct a roadmap review

The IEA Guide includes recommendation how to make such a roadmap work successful. Additionally the review process of the well-designed and nearly completed draft document is highlighted and seems to be import in that third roadmapping process phase. Some Lessons learned due to the review cycles are formulated in the IEA Guide.

The D4 activity group of SHC Task48 suggest focusing on setting up action plans with specified measures to achieve the vision target of SHC Technology. The developed action could specify measure from different fields of action – see the Austrian roadmap, like

- Trade sector (Stakeholder from industry, producer, trader system supplier. Federation
- Research & development (Research institutes, universities and companies)
- Legal and funding frame conditions (State, provinces and municipalities)
- Accompanying measures (Public administration, federation, industry representatives ...)

Important questions should be considered by setting up an action plan for the SHC roadmap:

- How can the objectives be reached?
- Which frameworks have to be changed, which laws have to be introduced?
- Which of these actions has to be done by whom? What cooperation is necessary?
- What are best practice examples of the countries/companies/etc.
- Where the objectives have already been reached and explain how they were reached? Find best practice examples of the countries/companies/etc. !!!
- What are the benefits of the implementation of the roadmap for each stakeholder?
- What methods lead to successful action plan? Workshop and conferences of all involved people, calculations and simulations..?
-

With regard to roadmap action plans for SHC technologies some selected from International, European and national roadmaps are highlighted here:

- The *Technology Roadmap Solar Heating and Cooling of the International Energy Agency* lists technology development actions and milestones for certain timespans. The technology action and milestone concern specify solar technology areas like the solar heat, solar heat for cooling, thermal storage, hybrid applications and advanced technologies. As an example for solar heat application Figure 8 displays developed actions and milestones to be achieved in a defined time frame and addressing different stakeholder groups. Figure 9 lists action and milestones for the policy framework.

This roadmap recommends the following actions:	Milestone timeline	Stakeholder
Integrate solar collectors in building surfaces.	2012-20 (Develop new integrated building products by 2020)	Research institutes, SHC industry, architects/ building industry
Use alternative materials, technologies and manufacturing techniques for system cost reduction and performance improvement.	2015-20 (30% system cost reduction by 2020)	Research institutes, SHC industry
Address challenges in system design by development of standardised kits and plug-and-function systems.	2012-20	SHC industry
Expand development of collectors that cover temperature gap between 100°C and 250°C.	2012-20	Research institutes/universities, SHC industry
Address challenges in development of medium to large-scale systems by developing pre-engineered solutions and improving system design knowledge.	2012-20	SHC industry

Figure 8: Action plan and milestones for solar heat (Source IEA Technology Roadmap - Solar Heating and Cooling2012)

This roadmap recommends the following actions:	Milestone timeline	Stakeholder
Set medium-term targets for (nearly) mature solar heating and cooling technologies (solar low-temperature heat) and long-term targets for advanced technologies (high-temperature heat and solar cooling).	2012-25	Governments, industry associations
Introduce differentiated economic incentives – such as feed-in tariffs or renewable portfolio standards for commercial heat and subsidies or tax incentives for end-user technologies – by means of a transparent and predictable framework to bridge their respective competitive gaps.	Start 2012, phase out depending on development of competitiveness	Governments
Make economic incentive schemes consistent over a period to allow time for industry to plan and develop with certainty. Avoid "stop-and-go" policies by separating funding for support schemes from annual state budgets.	Start 2012	Governments

Figure 9: Action plan and milestones for policy framework (Source IEA Technology Roadmap - Solar Heating and Cooling2012)

- The European Solar Thermal Technology Platform ESTTP published a document with the title *'Solar Heating and Cooling for a Sustainable Energy Future in Europe'*. In this roadmap the chapter "Deployment roadmap" is introduced by:

'This chapter outlines a roadmap for the deployment of solar thermal energy towards the implementation of the Vision 2030 discussed above. The basic principle of solar thermal is always the same, and similar components and technologies are used in all applications. However, there are certain technological and market development challenges. This chapter addresses key areas for the use of solar thermal energy, which include buildings, industrial processes (desalination and water treatment) and district heating. An introduction to each of these sectors is followed by a table giving an overview of the current situation, and the predicted stage of development in 2020 and 2030, taking into account a number of technological and market development parameters. This Deployment Roadmap serves as the basis for the detailed Strategic Research Agenda, assuring that the proposed research fields are embedded into the requirements arising from expected market needs. The Strategic Research Agenda describes in detail the necessary R&D work. It is expected that the energy and climate crisis will drastically change the heating market over the next two decades. In new buildings, we expect a tightening of energy performance requirements, including the obligatory use of renewables, which will be increasingly required by governments and the market. In the existing building stock, energy savings will become the key driver for renovations, and district heat operators will become more interested in, and possibly be forced to increase the share of renewables. For industrial process heat and cooling, the key driver will be the need to reduce growing energy costs, and possibly the cost of emission allowances at the carbon market, as long as they are applied to heat consuming processes. All these developments will lead to a sharp increase in the use of solar thermal technologies and the subsequent need for new and advanced technologies in this field' from [IEA R SHC, page 38]

This strategic document indicated three fields

- Towards the active solar building
- Industrial process heat, including water treatment and desalination
- District heating and cooling

Figure 10 lists action and milestones for the process heat in the industrial sector from 2007, 2020 and 2030 a

INDUSTRIAL SECTOR, PROCESS HEAT		
2007	2020	2030
TECHNICAL		
Fundamental research		
• Collectors and systems for temperature levels of 80-250°C • R&D on new/innovative materials and concepts for heat storage (such as latent heat and phase-changing materials) • R&D on heat storage for temperature > 100°C • Simulation tools for planning SHIP systems	• R&D for storages > 100°C • New materials that can be used for ST applications • Collectors and systems for high temperature levels (> 250°C)	• Next generation
Development in industry		
• Solar Thermal Collectors with operating temperatures of 80-250°C • Systems with water, thermal oils, steam and air • Double glazed collectors and anti-reflective-glass • Parabolic collectors and CPC collectors	• Product development for heat storages • Standardisation of system concepts • Solutions for stagnation problems in big systems • Solar roofs for industry buildings	• Next generation
Identified demonstration/lighthouses		
• Systems for hall heating, drying processes, washing and brewing - system size: a few hundred kW • Systems for cooling e.g. winery	• Large systems with high temperature heat storages • Large systems of more then 2000 kW • Plants in all industry sectors (food and beverage, textiles chemicals) and different applications (washing, drying, boiling, pasteurising and heat treatment)	• 100% solar heated plants and factories in each industry sector (operation temperature < 250°C) • SHIP for applications that require high temperatures (> 250°C)

b

INDUSTRIAL SECTOR, PROCESS HEAT		
2007	2020	2030
MARKET		
Share of solar in different applications and regions		
• Worldwide installed capacity of about 27 MW_{th} (38,500 m²) • About 85 solar thermal plants with SHIP worldwide	• 4 GW_{th} (5.7m m²) installed capacity in EU27 for low temperatures (<100°C) • 0.4 GW_{th} (570,000 m²) installed capacity in EU27 for medium temperatures (100-250°C)	• 15 GW_{th} (21m m²) installed capacity in EU27 for low temperatures (<100°C) • 2 GWth (2.85m m²) installed capacity in EU27 for medium temperatures (100-250°C)
Education of professionals		
• No special training programs available; only regional activities, events or workshops • No knowledge in process engineering of integration of solar heat	• Planning guidelines for all applications for SHIP are standard in education for process engineers • Courses for installers and plant constructors are available	• Solar Thermal is a standard part of the curriculum at all levels in the education system • SHIP is standard in the education of installers and plant constructors • SHIP courses are available at university
Regulatory issues		
• Not yet	• All systems required to meet CE and Solar Keymark requirements and standards	• Renewable energy laws oblige the industry to use SHIP for a minimum share of required energy
Price / Performance		
• Company decision makers expect 3-5 years amortisation time • New ST-ESCO solutions are offered by only a few companies	• New business models are offered on the markets (guaranteed solar yields and contracting)	• Price/performance ratio is very competitive compared to traditionally fuelled processes for heating and cooling • Guaranteed Solar Result Contracts and other ST-ESCO solutions are standard for all system sizes, within the context of a widespread use of ESCOs in buildings

Figure 10: Deployment roadmap for solar process heat a9 Technology and b) Market (Source: ESTTP Solar Heating and Cooling for a Sustainable Energy Future in Europe 2012)

- The *Austrian Roadmap 'Solarwärme 2025'* emphasis four different fields of actions till 2025.. Namely this are a) specific sector activities, b) research and development, c) 'frame condition condition and d) accompanying measures. More than 100 separate measures are defined. The benefits are indicated for different scenarios (business as usual, forced activities, ambitioned activities) to be able to give a better overview of what happens if the measures aren't applied and if they are applied.

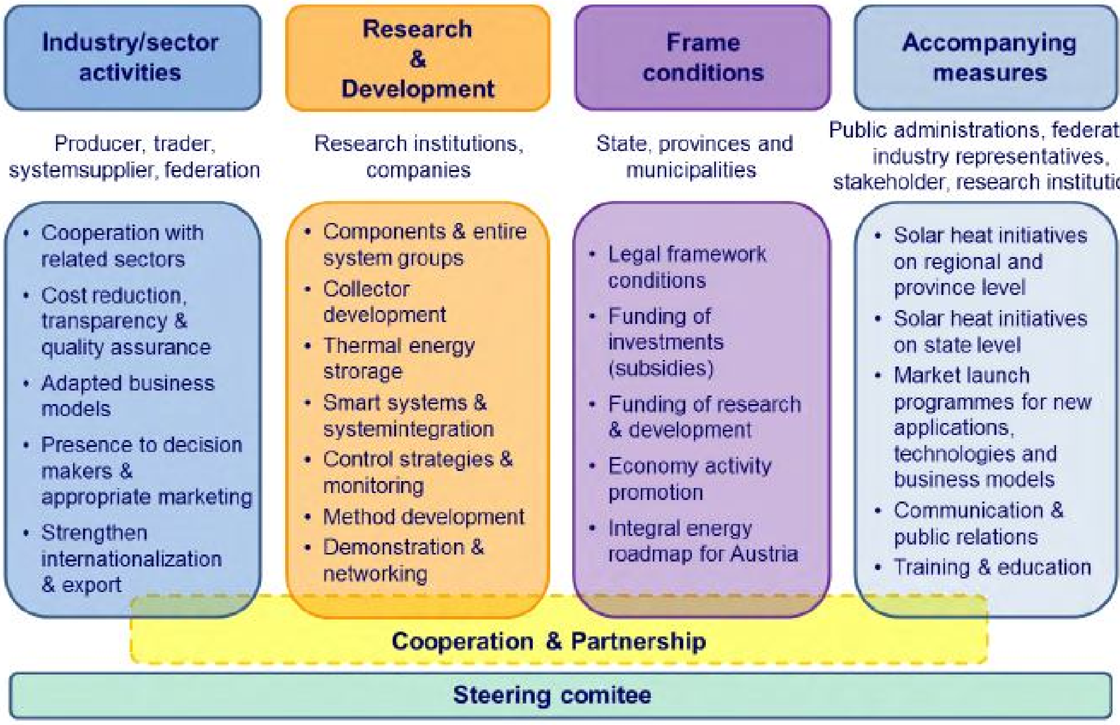

Figure 11: Provisions and activities clustered in fields of action. These four fields of action include over 100 single detailed activities and proposals which were identified during the roadmap process of „Solarwärme 2025“.

3.4.4 Phase 4: Roadmap implementation and adjustment

Phase four is dedicated to implementation and adjustment of the predefined action and measures of the roadmap. As well here the IEA Guide delivers many details and recommendation how to track and to launch the roadmap. Essential caption of the document are:

- Launch the roadmap
- Begin implementation
- Monitor progress and adjust the roadmap
- Manage expectations

Lessons learned: Roadmap implementation and revision

- Approach roadmapping as a “living process” that continues past the roadmap’s initial publication.
- Plan a successful roadmap launch to build awareness and create momentum needed to stimulate action.
- Designate the roadmap implementation body early in the process.
- Monitor key energy, environmental and economic indicators to track progress.
- Conduct regular roadmap revision workshops to adapt roadmap goals and priorities to changing circumstances.

Finally the D4 activity group of SHC task 48 repeats the lessons learned with regard to implementation and adjustment.

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6 Annexes

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Annex 2: Abstracts of existing roadmaps
Annex 3: Evaluation matrix of existing roadmaps