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The role of absorption chiller demonstration projects in a climate-friendly, energy-efficient restructuring of the refrigeration sector

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Abstract

Socio-technical research within a larger research and demonstration project on innovative low-temperature absorption chillers aims to identify the drivers of and barriers against a fortified market dissemination and implementation of this technology. My contribution addresses preliminary results from a constellation analysis, focusing on the connection between demonstration projects as “local experiments” (in socio-technical niches) and current developments in the existing socio-technical system of refrigeration supply (regime change). I will consider whether and how both levels of action contribute to larger sectoral changes.

Keywords

Multi-level perspective, technological innovation, refrigeration, energy efficiency, factors of influence

Relevance of absorption cooling for climate protection

Up to now, refrigeration has played a minor role in discussions, programs and strategies for a climate-friendly, CO_2-saving transformation of the energy supply. However currently, around 14 percent of German power consumption is used for refrigeration alone, creating 5 percent of direct and indirect German greenhouse gas emissions (Heinrich et al. 2014, 24).

All types of refrigeration and air-conditioning technologies are experiencing growing markets (Clausen 2007, 8; Davis 2015). Especially the market for air conditioning is rising rapidly.

World sales in 2011 were 13 percent higher than in 2010 (Cox 2012). The refrigeration sector is likely to grow substantially in the upcoming years. Demand for air conditioning alone will have risen 50 percent from 2006 to 2020, mainly in the commercial and household sectors (Henning et al. 2012b, 191). The International Energy agency predicts a 12.7 percent yearly growth of chilled areas world-wide by 2020 (Eicker 2012, 147, 2010; Adnot et al. 2003).

Absorption refrigeration has only been used in certain fields with specific preconditions and requirements in the medium- and large-scale performance range. It is employed mainly for commercial and industrial refrigeration with typically high refrigeration capacities – in breweries, refrigerated warehouses and other applications with high cold demand (Jakob 2012, 153; Förster 2013, 12; Schindler 2010, 10). The majority are high-temperature applications direct-fired with gas or oil or heated with steam or hot water (Schindler 2010, 62; Eicker 2012, 150, 2011; Förster 2013; Henning et al. 2012a, 168; Probst 2012, 52).

With reference to climate protection and the necessary transformation of energy supply, researchers predict and demand a substantial rise in thermally driven refrigeration, of which absorption-type refrigeration technology has by far the largest share. This assessment has been nurtured by a new generation of absorption chillers offering significant technological improvements (higher performance, lower investment costs and space requirements) which encourages low-temperature application in particular (Petersen et al. 2013; Ziegler et al. 2013; Eicker 2012; Pecka 2014; Förster 2013, 12; Clausen 2014; Schindler 2010).

Expectations regarding the possible environmental benefits of thermally driven cooling are based on savings in primary energy through the use of heat instead of electricity as operating power (especially from waste heat, heat from combined heat and power generation, and renewable sources) [and] the possibility of using free-heat capacities during the summer months, thereby making a considerable contribution to the decrease in summer peak loads in the electricity net. (Probst 2012; Dittmann et al. 2014; Eicker 2011; AGF) 2013; Dittmann et al. 2014; Henning et al. 2012a, 207; 231-232)

Recent research has focussed on the technological and economic aspects of refrigeration (Albers et al. 2011, 1855 & 1858-1860; Mittelbach 2011, 43; Petersen et al. 2013, 48; Probst 2012, 19–22; Ziegler et al. 2013, 15 & 24; Fichter et al. 2012; Buchholz et al. 2012; Clausen 2007; Jakob 2012, 2008; Matthes & Schröter 2011). However, science and technology studies say that a fairly broad range of factors influences the diffusion and implementation of innovative technology. Up to now there has been a knowledge gap regarding integrative views on the success factors integrating communicative, organisational, regulative and legislative, social and other factors.

Socio-technical research on absorption chiller innovations

In the following I present the preliminary results of socio-technical research that is part of the ongoing research and demonstration project on innovative absorption chillers “Field-test absorption chillers for combined heating, cooling and power systems (CHPC)” (Feldtest Absorptionskälteanlagen für Kraft-Wärme-Kälte-Kopplungs-Systeme or FAkS). The main goals are the demonstration and monitoring of a new type of absorption chiller, developed by the Department of Mechanical and Systems Engineering of the Technische Universität Berlin (TUB). Funded by the German Ministry for Economics and Energy (BMWi) within the research programme “EnEff: Stadt”,[1] it has a duration of five years (2013–2018).

Socio-technical research within FAkS, carried out by the Center for Technology and Society of the TUB, aims at identifying drivers and barriers for further market dissemination of innovations in the field of low-temperature absorption-type refrigeration.

Based on approaches from science and technology studies (multi-level-perspective, innovation studies), the analysis targets two levels of investigation: the macro level of the refrigeration regime as well as processes and experiences within the field tests, which can be considered local experiments or demonstration projects in a socio-technical niche.

Preliminary results of a constellation analysis

In the following, I address preliminary findings from a constellation analysis on the question of the factors promoting or inhibiting a fortified dissemination of low-temperature absorption refrigeration. It shows whether and how both levels of action – demonstration projects as “local experiments” (in socio-technical niches) and current developments on the regime level – may contribute to larger sectoral changes.

The method of constellation analysis was developed at the Center for Technology and Society. It is based on approaches from sociological technology studies and on experiences with inter- and transdisciplinary research. Constellation analyses can be applied to diverse tasks and objectives related to inter- and transdisciplinary communication – for example to integrate different problem views, knowledge and solution approaches.[2] Practical implementation comprises a communicative fusion of different disciplinary and practical perspectives within a workshop. The discussion is structured by drafting a graph. In this visual representation of results, four types of elements are distinguished (see figure 1): Actors, technology, signs (Zeichenelemente), and natural elements (not used in the following graph). (For further in-

[1] http://www.eneff-stadt.info/de/neue-technologien/projekt/details/feldtest-absorptionskaeltetechnik-fuer-kwkk-systeme/ [retrieved 2016/05/30]

[2] http://www.tu-berlin.de/ztg/menue/projekte_und_kompetenzen/konstellationsanalyse/v_menue/die_konstellationsanalyse/ [retrieved 2016/05/30]

formation about the method see for example Ohlhorst & Kröger 2014; Schön et al. 2007; ZTG 2015)

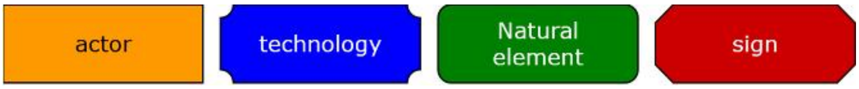

figure 1: Elements of a constellation analysis

The constellation analysis in FAkS is based on a literature analysis and a discussion with team colleagues from engineering. It will be complemented by expert interviews in future. Current results show that the following factors promote or impede a fortified diffusion of absorption chiller innovations (figure 2):

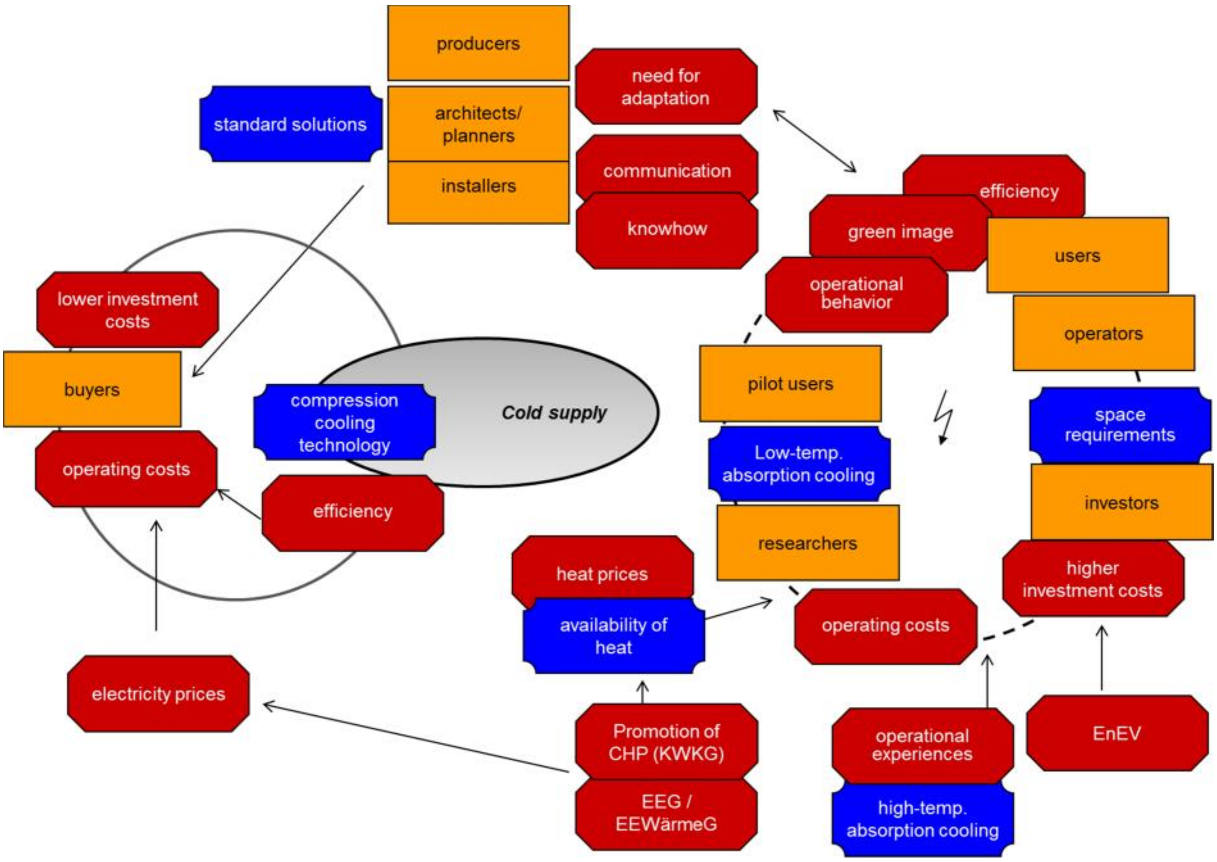

figure 2: Promoting and inhibiting factors in a fortified dissemination of low-temperature absorption chillers

A first cluster of factors influencing the diffusion of innovative absorption chillers is grouped around electrically driven compression refrigeration technology, the current dominant technology of the refrigeration supply regime. This sub-constellation is well established, stable, and therefore works against an increase in absorption chiller innovations.

Investment costs are generally an important decision criterion for buyers. Investments costs for compression chillers are still relatively low (compared with absorption chillers). Rising electricity prices work against compression refrigeration and thus promote absorption refrigeration, but rising energy efficiency (= decrease of power consumption) partly compensates for this effect.

Producer, planner and installers act independently within a stable, differentiated business segment. Activities and products of these actors are well coordinated by technical and planning standard solutions which facilitate a smooth application of the technology and communication with customers.

A second cluster of factors of influence is related to absorption refrigeration itself, which up to now has existed in only a small market niche. In this sub-constellation, high-temperature applications in the medium- and large-scale performance range predominate. Low-temperature absorption chillers have been on the market for only a few years.

There are several aspects affecting the decision-making of investors, operators and users of absorption chillers.[3] The most important aspects for investors are space requirements and investment costs. Despite recent advances, both are higher than for compression chillers. The higher investment costs are partly compensated for by the Energy Performance of Buildings Directive (EnEV): As this regulation focuses on the primary energy demand of buildings, the implementation of absorption chillers can compensate for example for insulation and help to reduce related costs. The most relevant factors for operators and users are the operational behaviour, energy efficiency and green image of the technology. The operational behaviour of absorption chillers can confuse actors, because they need more time for start-up than do compression chillers. In addition, absorption chillers work less efficiently than compression chillers. This affects operating costs in a negative way. System efficiency is still too low. The technology has a positive image, although the implemented systems did not always fulfil expectations. The green image of absorption chillers was the main driver for absorption chiller implementation until approximately the beginning of the century, and it is still important. Companies use it to create a positive public image. Not least experiences with high-temperature applications affect investment decisions. Since implemented refrigeration systems do not always work well, there are positive as well as negative operational experiences.

[3] In the compression refrigeration sub-constellation, these actors are termed “buyers”.

The outcomes of recent research on absorption refrigeration and pilot applications are an important driver of a fortified dissemination of absorption chillers. Recent research and development has helped to remove the essential technical problems.

The supply side is insufficiently developed. Absorption chillers are mainly produced by established producers of compression cooling machines. Absorption chillers are only an additional business, responding to user demand. These actors have little interest in investing in absorption refrigeration technology. In addition, there is a growing number of new producers of absorption chillers: start-ups, which have been more or less successful in the market up to now.

Standard solutions for absorption refrigeration systems are not yet available. Thus every installation has to be planned and designed individually. This is accompanied by a higher need for communication and coordination between producers, planners and installers. As planners and installers do not always have the necessary competences for absorption refrigeration, communication is more complicated and time-consuming. Due to a lack of know-how when it comes to absorption refrigeration, planners often recommend absorption chillers for applications they are not suitable for, or they opt for the installation of compression plants.

Further dissemination of low-temperature absorption chillers is, thirdly, influenced by changing energy and climate policy. Recent developments in the heat and electricity sector have induced an increasing demand for new, energy efficient technology and public research in this sector. Promotion of combined heat and power and renewable energies (German Renewable Energies Act (EEG), Renewable Energy Heat Act (EEWärmeG), and Combined Heat and Power Act (KWKG) and related regulation) also created and opened up new heat sources for thermally driven refrigeration (heat from cogeneration, solar heat, waste heat from industrial processes, district heat.

From niche to mainstream?

In terms of the multi-level perspective, the results of constellation analysis show that the fortified dissemination of current absorption chiller innovations is influenced by:

- a relatively stable refrigeration regime with compression refrigeration as the dominant technology, comprising an established, but very small market niche for high-temperature absorption chillers;
- a socio-technical niche around low-temperature absorption chiller innovations; and
- developments in the electricity and heat supply regime.

Current changes in the refrigeration sector and a potential increase in the role of absorption refrigeration result from a coincidence of mutually influencing developments: Changes in the heat and electricity regime increase the number of available heat sources and push the diffusion of energy-efficient absorption chiller innovations. Simultaneously, technological progress in absorption refrigeration technology meets actors on the demand side looking for innovative solutions, creating new socio-technical niches. Therefore, demonstration or pilot projects are one important driver of a fortified dissemination of low-temperature absorption chiller innovations. On the other side, the established electricity-based refrigeration regime is still supporting the implementation of compression refrigeration. Both the need for development on the supply and implementation side and technology-related uncertainties hamper a fortified dissemination of innovative low-temperature absorption chillers.

Finally, a look back at the title of this session. Is "from niche to mainstream?" probable for absorption chillers? And – with refer to climate protection and CO_2-saving – is it desirable?

Trying to find answers is a little like looking into a crystal ball. The developments of renewable energies have themselves shown that future developments are scarcely predictable, and unforeseeable progress is possible.

According to the state of the art today, though, it seems that "mainstream" is not the most probable future for absorption chillers – and probably not even the most desirable. Absorption chillers are far from mainstream. With regard to the broad range of fields of application for refrigeration technology, it is even far away from really challenging compression refrigeration. It is more likely that new and enhanced market niches develop, for example coupled with combined heat and power generation, solar thermal plants and/or district heating – therefore depending very much on the future role of solar thermal heat and other forms of regenerative based heat providing, the share of renewable electricity or the role of power to heat the future energy supply regime. This may also be crucial for the environmental benefit of thermally driven refrigeration and thus the desirability of a regime change towards thermally driven refrigeration.

Notwithstanding this, all these new technological options and couplings need new forms of organisation, cooperation, and communication; new rules, institutions, and business models; as well as other social innovations. The willingness and ability of the actors involved to enact these changes – from engineering, business, policy, the supply side, and the use side – will be as crucial as the technological and economic efficiency of absorption refrigeration technology.

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