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Authors		
Author(s) Name	Organisation	E-mail address
Jens Petter Johansen	NTNU Social Research	Jens.petter.johansen@samfunn.ntnu.no
Jens Røyrvik	NTNU Social Research	Jens.royrvik@samfunn.ntnu.no

Abstract

This memo provides an overview on barriers and enablers for utilization of surplus energy (i.e. heat, CO-rich off-gas) and includes input from HighEFF industry partners based on workshops as well as case-studies of industries conducted in 2017/2018.

Table of Contents

Innhold

1 Introduction

This memo provides an overview on barriers and enablers for industry implementation. The main focus in RA5.1 in 2017/2018 has been on barriers and enablers for utilization of surplus energy (i.e. heat, CO-rich off-gas) from industry processes. The results includes input from HighEFF industry partners based on workshops, interviews, field visits, document studies and case-studies conducted in 2017/2018. While this work will continue in 2019, the several results and practical insights have been revealed in the conducted work and will be briefly described in this memo. The work group also see the contoures of improving the theoretical research field on barriers and enablers based and several research papers are planned for 2019 based on activities in RA5.1.

This memo is updated yearly throughout the lifespan of HighEFF as new cases are explored. The document will first revisit existing barrier models (Chapter 2), before describing key results and insights from the 2018 activities (Chapter 3). Based on this empirical overview we provide novel theoretical and practical perspectives on barriers and enablers (Chapter 4) which will be continuously explored within RA5.1.

2 Previous research and barrier models (SOTA)

This chapter provides a brief revisit on barrier models (See deliverable *D5.1_2017.05 SOTA Barriers and enablers* for å full review). The research on potential for energy efficiency often translates findings into barrier models, listing the prohibiting and enabling factors for implementing energy efficiency measures (EEMs). This tendency can be traced back to Hirst and Brown (1990) definition on what several scholars within economic sciences considers a paradoxical energy efficiency gap: *…the unexploited economic potential for energy efficiency, in other words, it emphasizes the technically feasible energy efficiency measures that are cost-effective but are not being deployed*. Following Hirst and Browns (1990) argument and the following research tradition on the energy efficiency gap, the non-implementation of economically and technological feasible solutions must be hindered by other factors. Research on (non-technical) barriers and drivers towards industrial energy efficiency contains key a priori assumptions; 1) there is a gap between present practices and state of the art technologies, and 2) this gap is not concluded due to *non-technical* barriers (Weber 1997). The research field on implementation of solutions for utilization of surplus heat is often framed within the same framework on barriers.

2.1 Barriers and enablers on external utilization of surplus heat

The most relevant study of barriers related to utilization of surplus heat, was conducted by McKinsey & Company on assignment from Enova in 2009 which concluded two reports on the potential for energy efficiency in the Norwegian industry and utilization of surplus heat (Enova 2009a, Enova 2009b). The study is based on similar barrier-models and assumptions of a technical potential, gap and non-technical barriers as the studies listed above. The study covered more than 95 % (76 TWh) of the energy used by Norwegian shore based industry identifying a *technical potential* of 12TWh of reduced direct energy use (energy efficiency), as well as additional 10TWh of utilizing surplus heat externally[1].

The main categories of barriers for utilization of surplus heat identified in this study was lack of external infrastructure (for excess/surplus heat), immature technology, lack of economically attractiveness, limited access to capital and low consciousness or competence.

[1] The McKinsey (Enova 2009a, 2009b) reports on technical potential of industrial energy efficiency have been contested by the Energi21 working group that costs are underestimated, quality (exergy) of surplus heat is not discussed and utilization of excess heat to district heating often implies complex projects and a less attractive need for long-term contracts.

1. *Lack of external infrastructure* to utilize excess and surplus heat is regarded as an important barrier for increased energy efficiency. Several industries are located too far away from district heating networks or other industries in order to utilize surplus heat in an economic viable way. However, some industries have mitigated this barrier by actively establishing other energy complimentary industries in proximity to the cluster (i.e. food industry cluster described in (Johansen 2012)).
2. *Immature technology (2)* also relates to uncertainties and perceived risk of adopting technologies that are not commercial off-the shelf. An important note is that the study was conducted in 2009 and several developments are evident within the technology areas which are also relevant for the next barrier.
3. *Economic attractiveness (3)* includes lack of profitability and uncertainties regarding development of electricity prices. Measures for energy efficiency can imply internal risks for transaction costs and interruptions in production, or other risks outside the company control such as dependencies, varying prices, and longevity of the business itself.
4. *Access to capital (4)* can be a barrier if the initiative is not prioritized due to competitive projects that require capital (Enova 2009b, Sorrell 2011). Even though energy efficiency measures are profitable in themselves, obligatory or strategically important projects (for example HSE or regulatory demands, modernization projects) can be prioritized. High investment costs of energy efficiency measures in combination with uncertainties and risks of long term electricity prices have according to the McKenzie (Enova 2009b) report is an especially important barrier for utilization of surplus heat from the aluminum industry.
5. The last barrier category *low consciousness and not available competence (5)* are not thoroughly examined in the McKenzie report, but are mentioned as a final barrier with high relative impact on the hindrances for energy efficiency in *non-energy intensive* industries. Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed (Sorrell 2011:6). This barrier is often connected to lack of energy management systems, which are most common in non-energy intensive industries. Similarly, lack of competence in different areas of the organization can hinder energy efficiency measures from being identified, properly assessed and implemented (Enova 2009b).

While we find that the first four barriers in different ways are relevant in our case studies, the fifth barrier is less valid in terms of the energy-intensive industries interviewed. However, low consciousness of possibilities of utilizing surplus heat can be considered a barrier for other relevant actors such as the municipality when regulating areal or approving energy solutions in building regulations. Also, we find that isolating the explanations of “non-utilized potential” as well as “stranded initiatives” conclusively based on such a barrier framework looses sight of actual showstoppers in these processes, interactions effects between barriers as well as possible enabling factors.

3 Overview of empirical findings

In this chapter we split between internal and external utilization of surplus heat. While the main focus in RA5.1 have been on external utilization on surplus heat several barriers and enablers have been revealed during the workshops, interviews and case studies which are briefly described in this memo (see *D5.1_2018.02a Memo describing data collected* for a full overview of data collected).

3.1 Internal utilization of surplus heat

While the involved industries note that most of internal heat-demand have been accounted for there are further potential for internal utilization of surplus heat to either energy recovery and power production or internal heat demand (i.e. heating of own buildings, low-temperature heat network).

3.1.1 Energy recovery and power production

While not the main focus of the work conducted, some industries are considering to implement energy recovery for power production. While this is not an exhaustive list some key non-technical barriers have been revealed in this work:

- Capital investment costs on techniqal equipment are mentioned as a key prohibiting factor. Yet, there are ongoing evaluations among interviewed industry on energy recovery solutions. Also, the possibility of installing several conventional engines are mentioned as a possibility to split up and lower capital investments and overcome this barrier through long-term investment plans.
- Long payoff time on investments due to low price of electricity. However, low electricity prices is a key frame condition for energy-intensive industries in the first place.
- An attempted project of energy recovery revealed another factor related to the need for boundary setting and organizational splitting of the energy central between a process plant and an energy company to account for emissions in the EU ETS system complicating the decions-making between the parties.
- An additional barrier revealed is that time constraints due to other capital intensive investments cause delays in decision-making for energy recovery solutions.

3.1.2 Internal heating

Some of the representatives interviewed note that there is potential to utilize surplus heat to heating of for example office buildings or mechanical workshops. While this is being considered, the relative energy saving potential are considered low, thus leaving less attention to these projects (although they might yet happen).

3.2 External utilization of surplus heat

Both workshop and case studie interviews indicate that the most prominent potential for utilizing surplus heat (even at lower temperatures) are through external utilization. We conceptually split between industries connected to district heating networks (3.2.1), bi-lateral collaborations with heat-demanders (3.2.2) and cluster models (3.3.3), while in practice there are often combinations of the three.

3.2.1 District heating

Some of the industries interviewed are already connected to district heating networks (DH). While source of surplus heating (cooling of off-gases, CO-rich off gas, other heating sources) are not exhausted new buildings and industry establishments within the concession area in the region can lead to increase outtake of surplus heat. Thus, several barriers and enablers are intrinsically connected to local and national frame work conditions for DH:

- Frame conditions for district heating is under severe change in among others building regulations, as well as continuously improved energy efficiency in buildings leave less need for DH.
- Municipality not having or upholding restrictions for connecting new buildings/industries to DH.
- Increased outtake of surplus heat to DH is connected to regional growth within (or by expansion of) the concession area for DH.

The interviews also involves three attempts at establish new district heating networks where all have stranded in the evaluation phase (conducted by external parties). The key barrier from the three stranded initiatives was lack of existing heat-demand however this overall barrier is also connected with 3.2.2.

3.2.2 Bi-lateral cooperation with heat-demanders

Most of our informants address the need for establishing new industries with heat-demand at appropriate temperatures to release the potential for surplus heat available. Establishment of new industries are outside the responsibility of heat-demanders (although some industries have shown to play an active part). Although

mostly heat-producing industries are interviewed and the data must be be expanded, the cases involves a change of perspective into demand-side barriers as well as public actors relevant for industry developments. This also draw the perspective towards localization factors in the specific regions hosting the surplus heat producing industries.

- Specific barriers for the demand-side industries (i.e. regulations and market for greenhouse production, land-based fish farming).
- Lack of regulated area in close proximity to process plant
- Lack of holistic thinking by public actors in the region (new industries are not connected to surplus heat industry)
- Attractiviness of the region and localization factors for heat-demanders.

3.2.3 Cluster models

Cluster concepts have been approached both by studying existing industry parks, a cluster in the making (localized business network) as well as contrasting these cases with interviewing single-plant industries. Thus, this work have studied both dynamics, organization and degree of formalization in existing clusters as well as barriers and enablers for establishing new cluster concepts. The main themes are partly overlapping with 3.2.2. and will be explored further in RA5.1 activities:

- Solo vs cluster thinking
- Organization and formalization of clusters
- Handling risk and uncertainties of interdependent synergies
- Holistic thinking (or lack of) by public actors in the region
    - Lack of regulated areal in close proximity to process plant
- Importance of network entreprenours, informal networks and trust for connecting local actors in cluster concepts.

Further work on cluster concepts will be continued as an ongoing collaboration with WP4.3.

4 Novel perspectives on barriers and enablers

Based on empirical findings from case studies in HighEFF new perspectives on barriers and enablers for external utilization of surplus heat has been revealed. The following includes main themes such as separating perceived and actually encountered barriers, change the focial point of analysis, re-think demand-side barriers, economization and mobilization of actors as well as studying industrial symbiosis dynamics.

4.1 Perceived, encountered and imagined barriers

A majority of the barriers discovered in previous research as well as in HighEFF workshops must be considered *perceived* barriers. Discussions and workshops on possible barriers explaining the lack of utilization of surplus heat are important starting point. However, the barriers revealed are often perceived and not necessarily encountered. Thus, RA5.1 are investigating cases of ‘failed attempts’ in order to also reveal encountered barriers directed at concrete initiatives. This work also revealed the contoures of imagined barriers which are not necessarily any longer true. Several of the actually stranded initiatives for bi-lateral collaborations for utilization of surplus heat was attempted several years ago for example before Enova was financing energy efficiency projects as well as publicly recognized focus on energy efficiency and industry clusters. Thus, some of the barriers revealed can act as imagined barriers even though they are no longer relevant. One example of this is a often named barrier of the unability of utilize surplus heat for greenhouse production due to agricultural regulations. However, there are successful examples at this indicating that the barrier is not necessarily national. Further work will involve investigating the mentioned ‘failed attempts’ and address

relevant policy actors (i.e. department of agriculture) to conclude the possibilities on such intitiatives and de-mystify imagined barriers.

4.2 Re-thinking demand-side and infrastructural barriers

A consequence of changing focal point of analysis is the implication of re-thinking the infrastructure or demand-side barriers. As the empirical findings suggests, several of the encountered barriers of bi-lateral collaborations for utilizing surplus heat are not related to the heat-producing party or energy related themes at all.

- Non-energy relevant barriers; frame conditions for new industries
- Localization factors: proximity to suppliers and markets, logistics, specific competence, regional factors

This work will be continued in 2019 in collaboration with other work packages in HighEFF. A key suggestion from this work will be to engage with heat-demanders (i.e. greenhouse, landbased fish farming) to investigate localization factors. These actors are not represented in HighEFF but are important perspectices in order to move this work forward.

4.3 Regional development and mobilization of actors

Strongly connected to demand-side barriers and as suggested by industry informants a key factor to increase utilization of surplus heat at low temperature levels are establishment of new industries. Thus, increased utilization is intrinsically intertwined with factors for regional development. This implies a change of analysis not only investigating barriers from the perspective of the heat-producing industry but expanding the view to regional factors and actors with the role of attracting new industries. A brief, although not conclusive overview of important actors identified in case studies is in the table below:

Actor	**Role**
Local energy company	District heating Local energy planning Dialoge with new industry
Municipality	Area and building regulations Local energy planning Attract and facilitate for new industry developments Uphold district heating regulation (tilknytningsplikt) Need to be aware of surplus heat resources
County councils (Fylkeskommune)	Facilitation and financing of local business networks Regional development
Regional development actors (Næringshager, utviklingsselskap)	Facilitation and advisory services to new industries
Others (local “champions”, investors, network entreprenours)	Facilitation, investment in new industries, enabling clusters

Table 1: Key actors and roles relevant for surplus heat utilization

Changing perspective to regional development and mobilization of actors imply a step away from barrier frameworks to focus on processes and enabling factors. A case study of how public actors can contribute to increased utilization of surplus heat as well as cluster concept will be elaborated in a journal paper in 2019.

4.4 Changing focal point of analysis

A theoretical implication of the previous sub-chapters is the need to change the perspective and focal point of analysis when studying barriers and enablers. The research field on utilization of surplus heat often place the heat-producer (i.e. industry with net surplus of heat) as the focal point of analysis. However, instructing the heat producer as the *subject* to the barriers often fail to discover and address the actual barriers preventing new industry and infrastructure developments. Changing the perspective of the analysis between the heat-producer, demander, cluster, municipality and region can reveal further barriers and better address the question on synergetic industry developments. This argument will be further developed in a journal paper in 2019 but will also have implications for further work within RA5.1.

4.5 Industrial symbiosis dynamics: uncertainties and resilience

The last novel theme addressed in this memo is uncertainties and resilience in industrial symbiosis. The studies of existing symbiotic relationship for utilizing surplus energy reveal the potential fragility of such concepts. Changing circumstances both internally, externally and inter-organizationally between the firms can continuously put symbiosis at test. For example changing events such as energy prices, technology, market and competitiveness, ownership of companies can trigger changes in the symbiosis and potentially exit of players. Studies of such relationships in RA5.1 show that both technical, organizational and social factors can contribute to increased resilience and maintenance of symbiotic relationships. These findings and insights will be presented further in a conference paper to ESREL 2019.

5 Conclusions and further work

The research on potential for energy efficiency often translates findings into barrier models, listing the prohibiting and enabling factors for implementing energy efficiency measures (EEMs), which has resulted in a variety of barrier models and different thinking about what is needed to realize energy efficiency. Research conducted in HighEFF gives depth to picture in especially two ways:

1. By focusing on the efforts of the HighEFF industries, context specific barriers and enablers are highlighted – showing the difference in industries, their organizational situations and specific frame conditions.
2. By this his we have been able to sort different typologies of barriers; a) separating perceived and actually encountered barriers, b) including different focal point of analysis – especially by rethinking from the demand-side of the barriers, c) economization and mobilization of actors and finally d) studying industrial symbiosis dynamics.

Further work will in addition to more cases and interviews with HighEFF industry partners include:

- Investigate localization factors of newly established heat-demanders (i.e. greenhouses, landbased fish farming) not utilizing surplus heat to gain further insight on demand-side barriers.
- Involve key public actors (municipalities, county councils, regional development actors) through interviews and workshops to increase awareness on surplus heat resources, holistic thinking regarding localization and regional energy planning.
- Include cases of energy efficiency measures outside the topic of surplus heat, to investigate internal implementation barriers.