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Report

Annex 15- Excess Heat:

Summary of Meeting May 26th -May 27th and Way Forward

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ABSTRACT

Abstract heading

Annex 15- Excess Heat sorts under the IETS (Industrial Energy –Related Technologies and Systems). It is an implementing agreement established under the auspices of the IEA. The goal is to show that there is potential for waste heat utilization in the world.

This report summarizes a few key points from the Annex 15 meeting in Lisbon, on May 26-27th and describes remaining work to be performed to complete Phase I of the Annex and the effort required to participate in Phase II of Annex 15.

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APPENDICES

1 Background:

Annex 15- Industrial Excess Heat Recovery- Technologies and Applications has a goal to show the potential for waste heat utilization in the industry. Annex 15 sorts under the IETS (Industrial Energy – RelatedTechnologies and Systems). It is an implementing agreement established under the auspices of the IEA.

The annex Manager is Thore Berntsson, Sweden.

In the first phase of the Annex the following tasks have been included:

1. Determining potential of excess heat recovery in the world
2. Document existing and emerging technologies/systems & Best Practices
3. Determine and use effective modes of information dissemination
4. Understand government policy and regulations

2 Meeting summary

A meeting in the Annex was held in Lisbon on May 26th and 27th 2014. The purpose of the meeting was for each participating country to present their projects and demos related to waste heat as well as go through the draft report from the Annex. The main challenge and topic for the discussion during the meeting revolved around the issue of how to define excess heat so that it can count as green energy under the EU ETS system as discussed in Section 2.2.
Notes from the meeting have also been provided by the Annex Manager in Attachment 1.

2.1 Presentations from each member country

Each country gave a presentation of their activities in excess heat. The presentation was to contain the following sections:

1) The role of excess heat in national energy research programs

2) Major R&D projects, including priorities regarding new technologies

3) Major demo projects or applied case studies

4) Example(s) of case studies

The presentations can be found here:

https://app.younited.com/?shareObject=a8aaa763-910b-7d44-d72d-8b37951a5337

Norway's presentation is shown in Attachment 2.

2.2 News from the IEA

Nine countries have signed the Annex 15 implementing agreement, the only agreement dealing with waste heat in industry.

Member countries: Sweden, Norway, Denmark, Netherlands, Belgium, Portugal, US , Korea, Germany Finland, Italy, Spain, Japan, Switzerland are interested in joining.

2.3 What is excess heat?

Excess heat produced from fossil fuels it is not green according to the NGO's and should not count in the EU ETS system. However, there is an agreement in this committee that excess heat is excess heat no matter if it originated from burning fossil fuels. One argument for this is that even when burning biomass which is considered green energy, 30-40% of theCO_2 (emissions should count as emission according to LCA studies.

However, if excess heat is to count in the EU- ETS system, it can only count if you cannot use it internally. Only then are you allowed to take it as green electricity. So the question becomes can you upgrade the heat using heat pumps and reasonably utilize it internally? If not, then it can be exported externally and counted as green electricity and be viable for subsidies. The challenge is how to avoid industry not optimizing processes in order to sell the excess heat. There have been examples where the sale of excess heat has promoted low efficiency processes. It is in principle possible to cheat in CHP plants if the tariff for green electricity is too high.

Another challenge is that there must be an economy aspect in the definition as well since the implementation of waste heat recovery costs money that may not be available in the industry. Therefore the definition of excess heat must contain the following key components:

Industrial excess heat is heat which cannot be used for energy saving in an industry, for technical or economic reasons, but which can be used internally through new technologies or be used externally.

2.4 Goal Annex 15: Develop an overview of Excess heat potential

Goal: Show the world that there is a potential in excess heat

Two approaches are possible to estimate what potential excess heat is available

The first is a Top –Down approach where one starts from primary energy assumptions used by the DOE, USA. Here a series of energy footprints can be used with the following losses:

- Boilers: 20% loss
- Steam pipes: 20%

- HX: 15%
- Power gen: 24%

The second is a Bottom-up approach like what was used in the ENOVA report for waste heat in Norway. Here questionnaires or even measurements are used to obtain representative data. This works well for energy intensive industry sectors with a small number of companies per sector. A conversion efficiency from primary energy to final energy use in industry of 75% is assumed. The challenges are how to obtain good responses from questionnaires? Generally European countries have to make environmental reports in industry so data may already be available for many industries. One can determine the excess heat per fuel used for a certain industry then extrapolate to others where data are not available. The benefit of the Annex is that there could be a collaboration between countries in these studies.

2.5 Rationale for Norwegian Participation in Annex 15

Norway is ahead in the area of waste heat utilization compared to the rest of Europe. This is evidenced by our national effort on characterizing waste heat sources in the 2009 ENOVA report. The report is now used as an example to follow in other EU countries. Norway also has many DEMO and research projects in the waste heat utilization area. At the same time Norway has a lot to gain from participation as it is an avenue to help influence the IEA and EU as they develop recommendations and legislation relating to waste heat utilization and energy efficiency in general, and how to define waste heat in the EU ETS. It is therefore important that Norway participates in Annex 15 and shares our expertise in order to advance this area further to improve implementation of energy efficiency measures in industry.

2.6 Remaining Work for Norway's participation in Annex 15- Phase I:

The following was suggested by the Annex 15 management for contributions from Norway for completion of Phase I:

- Provide status for CO_2 bottoming cycles for the Annex 15 report
- Write up a word document with key examples of demo projects to be included in the Annex 15 report
- Be active about reviewing new versions of the report
- Fill out earlier questionnaires - not filled out by Norway
- Contribute to writing small sections of the report

The following amount of remaining work effort for Phase I is proposed by the Annex Management:

Hours:

- 2-3 working weeks for the report
- 2.5 days for participation in final meeting and 2 telephone meetings

Direct cost:

- 2 telephone meetings, and one face to face meeting in February in Copenhagen
    - Phone- or web-meeting 23 September 2014, starting 15:00 Central European Time
    - Final meeting in Copenhagen: 24-25 February 2015

2.7 Phase II Proposed Work - Starting March 2015

For Phase II Member countries will commit to Annex 15 participation like the IEA requests:
Each participating country in an Annex should commit that they want to be in the Annex and be prepared to continue with:

- X amount of person weeks per year (1.5 MM suggested)
- x # travels, x # phone meetings.(2 travels suggested)

For the Phase II continuation all members will sign such an agreement for Annex 15.

2.7.1 Technical Content of Phase II

- Potentials for waste heat, theoretical, practical and economically viable ones
  - Potential by sector
- Framework conditions necessary to implement waste heat utilization
- Workshop for industry on excess heat-visibility
  - One in beginning (April-May) one at the end

2.7.2 Proposed Duration and Effort involved for Phase II

The following duration and effort is proposed by the Annex management for Phase II:

- Duration: 2 years.
- Budget: 1.5 MM per year (135 h per MM) , plus 2 travels
- Participating countries do not need to pay annex manager, this is paid by Sweden, only national costs need to be covered

IETS Annex 15 – Excess Heat
Notes from Workshop in Lisbon 26 – 27 May 2014

Attachments
1) Agenda
2) Presentations and list of participants could be found at https://app.younited.com/?shareObject=a8aaa763-910b-7d44-d72d-8b37951a5337

1) Welcome	Welcome address from the vice president at ISEL.
2) Overview of industrial energy R&D in Portugal	Presentation by professor Clemente Pedro Nunes. (See web link above.)
3) News from IEA (Annex Manager)	At last ExCo-meeting in Trondheim, the following was decided: a) IETS shall work more with workshops, within an Annex or together with other IEA implementing agreements b) Annexes shall as far as possible be longstanding and broad annexes for a certain type of industry or technology(ies) c) An organization in a non IETS-country can be an observer in an Annex for one year, thereafter this organization must become a sponsor (USD 2000 per year) or the country must join the IETS IA (USD 10000 per year) d) In the future Annex Management should be cost shared, whereas national team work should mainly be task shared. e) All participants in an annex shall when joining submit a written statement, based on a template, in which amount of work, type of work, and funding for e.g. travel shall be defined. (Regarding the last item, this kind of statement will be applicable in Phase two in Annex 15.)
4) Annex report – Status overview	The general structure was approved. The following changes were suggested: a) Possible future policy instruments in industry forecasted by large international organisations. b) Methods is lifted from Chapter 2 and becomes an own Chapter 3 (including “advanced composite curves”). c) Cooling should be included as way of use excess heat d) Technology sub chapters should be updated and reflect input from NT:s. e) The definition was discussed and a new version will be distributed for comments.

5) Ongoing R&D activities in participating countries.	The presentations could be found via the web link above.
6) Excess Heat – a sustainable resource?	A presentation by Simon Harvey and Thore Berntsson about green, white and black excess heat was discussed. It was concluded that it is important to distinguish between green, white and black levels of excess heat. The green level is when all excess heat stems totally from green energy sources, white is excess based on fossil energy inputs provided that this cannot be used technically or economically in a reasonably way internally, i.e. “true” excess heat. Black is based on fossil fuels but could be used internally and shall hence not be considered as usable excess heat. There was a long discussion about how to identify technically and fiscally when heat should be considered as true excess heat. It was concluded that this question must be discussed further in the autumn. Thore presented novel pinched based advanced curves that could be used to identify true excess heat. These curves will be described in the report.
7) Excess heat - amounts and temperature levels in different industry types	Anders presented information included in the report (see web link above for the presentation). (See item 11 regarding the decision about how to proceed.)
8) Approaches for identifying industrial excess heat-	The presentation by Anders about methods used in submitted reports and found in literature was discussed. The general problems of questionnaire based surveys are: • Getting a high reply ratio, • and uncertainty about the accuracy of the data provided by the respondents. However, NT:s from both Norway (Marit) and Sweden (Mats) presented projects with a good reply ratio. The reason might be that in several countries annual environmental reports are required and the respondents therefore had easy access to part of the data. These environmental reports are official in many countries and could partly be used as a source for information..
9) Technologies and Systems	Anders Åsblad presented information included in the report (see web link above for the presentation). The Annex Manager will ask the NT:s about further information on technologies and systems.

10) Policy instruments for excess heat	In the introduction, Thore showed: • "Advanced composite curves" • Future possible CO2 charges according to large international organisations From this it is obvious that a future uncertainty about such charges is very high. Future CO2-charges will influence the interest and the economy for excess heat use to a very high extent. This will be exemplified and quantified in the report. • Thore also showed slides about other possible instruments and indicated which of these will have a positive or negative influence on the use of excess heat (see presentation "Policy Instruments Residual heat"). This will also be discussed in the report. From the discussions about policy instruments in the different countries it was obvious that policy instruments differ widely. The Annex Manager will distribute a questionnaire about policy instruments to be included in the report.
11) First discussion on work in Phase 2 and common projects within e.g. EU	Possible areas for phase 2 was discussed and the following were identified • In-depth evaluation and inventory of excess heat levels • Methodology (how to perform an inventory in practice) • Policy instrument developments and influences We should use the network created in this group to facilitate funding from EU and other organisations. Marit will check if information about Spire could be distributed to this group.
12) Action plan regarding deliverables and obligations up to February 2015	An action plan was discussed: • In the autumn preparations should be made for a workshop about excess heat as a part of the IEA industry strategy group. Industry will be invited and among other things findings from phase 1 will be presented. A possible date for such a workshop would be in late April or early May It was agreed to have, if possible, web-meetings instead of telephone meetings. Deadlines and obligations: One week before each web-meeting and before the final face-to-face meeting an updated version of the report should be distributed by the Annex Manager. Each NT shall comment on this and suggest changes and amendments. The Annex Manger will also ask National Teams to provide specific input where necessary. The time required for National Teams for the remaining part of phase one is estimated to 2-3 man weeks.

13)	Next meeting	Dates to consider: 22 or 23 September (web-meeting) 25 or 26 November (web-meeting) 23-24 or 24-25 February 2015 (face-to-face meeting in Copenhagen.
14)	Site visit	End of meeting and departure to the visit at a cement industry. The manager at the cement plant spontaneously touched on most topics we discussed at or meeting and the problems with green, white and black excess heat were highlighted.

Göteborg, June 13, 2014

Thore Berntsson/Anders Åsblad

May 26-27, 2014

Excess Heat Utilization R&D in Norway

Presentation to Annex 15- Excess Heat

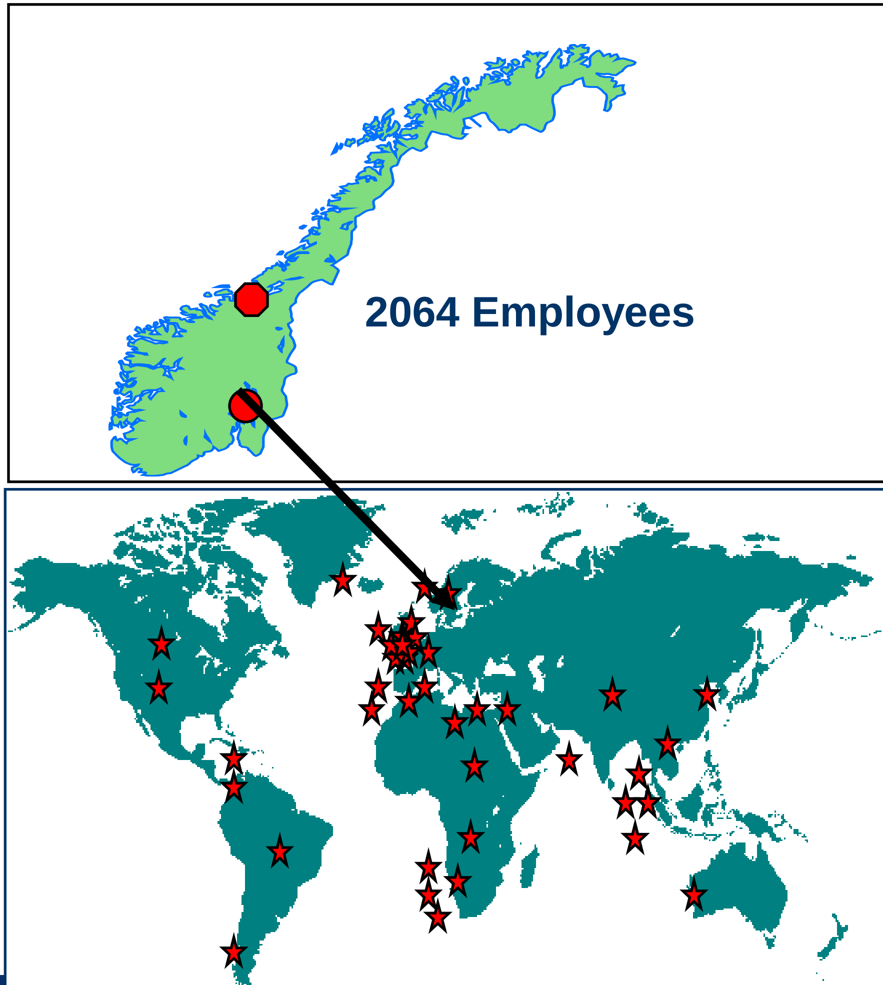
Workshop in Lisbon, May 26, 2014

Marit Jagtøyen Mazzetti, SINTEF Energy Research,

Dept of Energy Efficiency, Excess Heat Recovery

SINTEF – Research Center located in Trondheim and Oslo

SINTEF is one of the biggest independent research centers in Europe



Vision:
Technology for a better society

Business Idea:
Research-based knowledge and services for Norwegian and international customers

SINTEF aims to add value to our society in general and contribute towards sustainable development

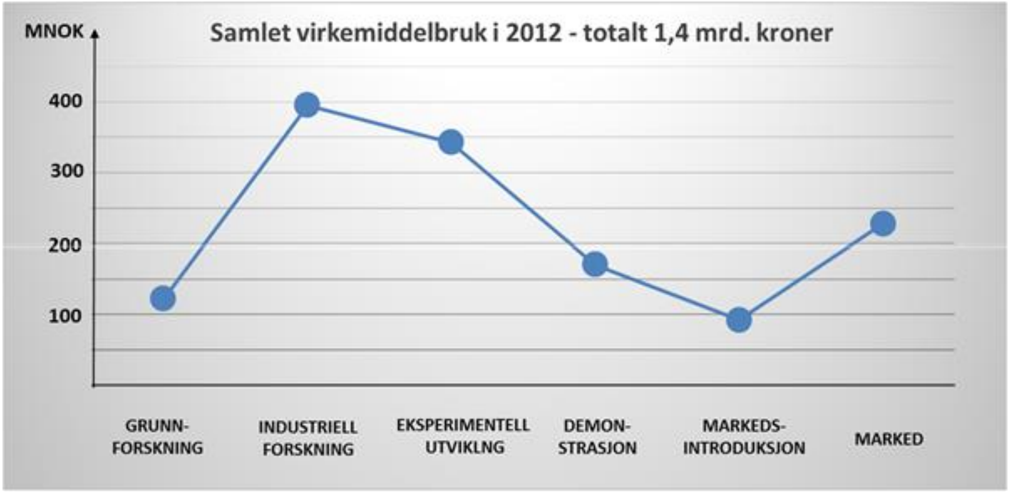
2013 Gross income 2.9 Billion NOK
Of which 17% from international customers in 67 countries

1. The role of Excess Heat in Norwegian Energy Research Programs – From "Energi 21"

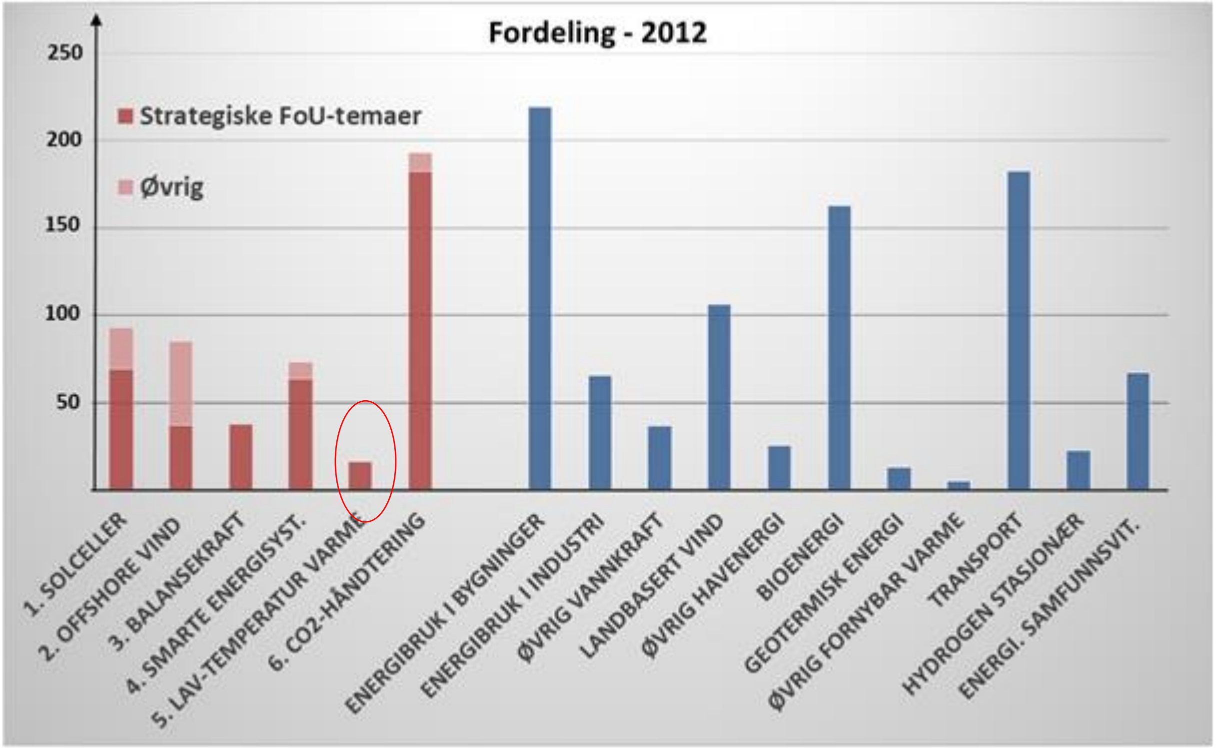
- Norway has a national foucs on R&D in the area of environmentally friendly energy technologies and CO_2 storage.
- Total expenditure in 2012 1,4 Billion NOK: 170 M€
- Energi 21 is the Norwegian national strategy for research, development and demonstration and commercialization of new environmentally friendly energy technology- 3rd edition to be published in 2014

Research Suppport :
Research Council of Norway
ENERGIX, CLIMIT and PETROMAKS2

Demos and Implementation
ENOVA; Gassnova, Innovation Norway and Transnova



Waste Heat Recovery one of 6 Strategic R&D Areas in Norway in 2011:



Distribution of Funds by Area -2012

SOURCE: Energi 21, Norwegian national strategy for research, development and demonstration and commercialization of new environmentally friendly energy technology- 3rd edition to be published in 2014

Distribution of Waste Heat in Norwegian Industry

- Norway 97.5% hydropower for Energy Supply. CO_2 emissions from transportation (30%), offshore oil/gas (29%), industry (25%) remaining from heating homes, agriculture, energy production (1.5%)
- ENOVA performed a "Waste Heat" study that characterized 70% of al waste heat in Norwegian industry -2009
- Total energy consumption for the companies participating: 53.7 TWh/yr.
- Waste heat available for use 19.2 TWh
  - T>140C -7.2 TWhr -power prod steam turbine , ORC, district heating
  - T=60-140-3.1 TWhr -power prod ORC, Stirling, direct district heating
  - T=40-60C: 5.8 TWhr -low temp district heating, upgrade heat pump
  - T=25-40C:3.3 TWhr -fish farming, ground heat, upgrade by heat pump

  - Goal of Norwegian industry is to reduce energy consumption by 20% by 2020. This totals 16 TWhrs annually
  - A study by Mc Kinsey in 2009 estimated that there was a potential of 12 TWhr reduction by 2020. However they estimated an unrealistic cost of only 11 B NOK in investments. Payback time would be 4 years on average.

2. Major R&D projects, including priorities regarding new technologies

KPN: COMPETENCE BUILDING PROJECTS

- CREATIV
- EFFORT
- ZEB
- ROMA

- **SPIN OFFS:**
- OPTILAM, PELAGISK, INTERACT, REMA 1000-
- ZEB

CREATIV Facts

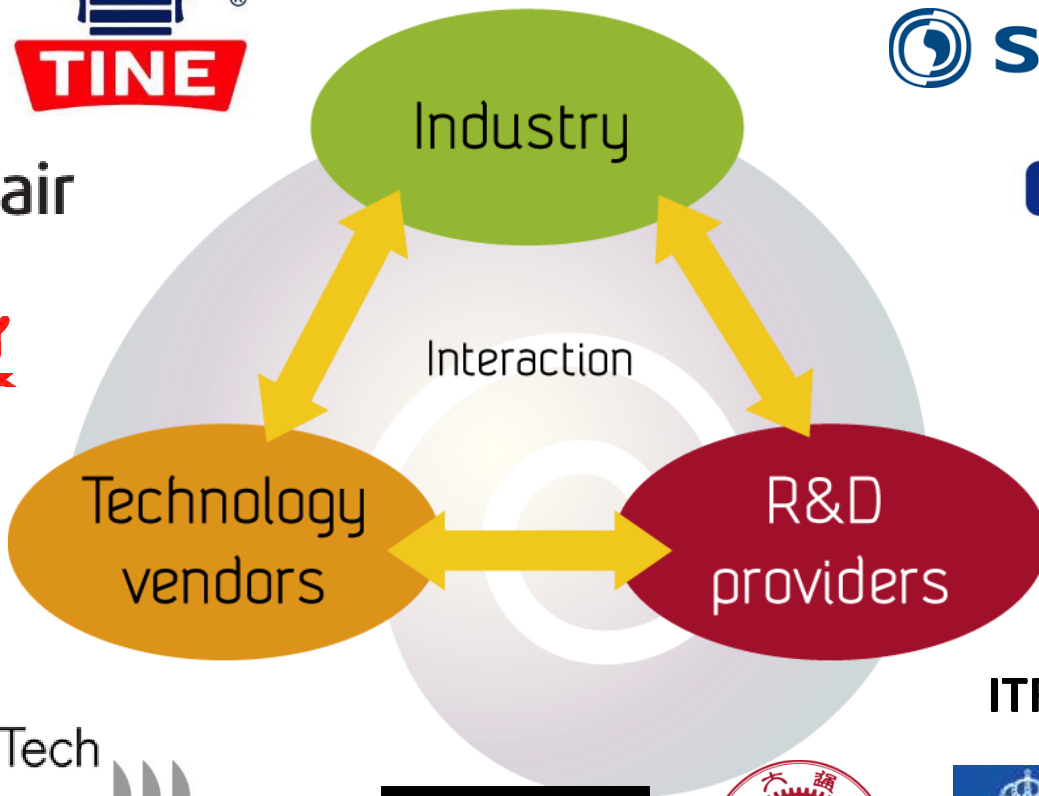
The objective of CREATIV is to demonstrate that more than 1/4 reduction in Norwegian energy consumption and greenhouse gas emissions is feasible by 2020.

Sub objectives

- Develop innovative knowledge and technology for waste heat recovery and efficient heating and cooling
- Educate and train specialists in industry energy efficiency
- Disseminate existing and emerging knowledge

- Knowledge-building project (KMB) including research and industry partners, supported by the Research Council of Norway
- Total budget 6.5 million € plus 3 million € in-kind
- Project period 2009-2013 (2015)

The key to success



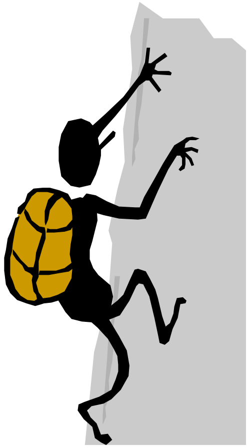
ITRI

Research platform for energy efficiency in industry

Areas of application:
- Metallurgy
- Pulp and paper
- Fishery
- Food production
- Supermarkets

Opportunities for energy efficiency
- Large amounts of surplus heat
- Need for heating and cooling
- Need for power
- Potentials for more efficient energy use

R&D challenges focused by CREATIV:
- Electricity production from surplus heat
- Innovative heat pumping technologies with CO_2 as working fluid
- Optimal thermal processing
- Industrial air ventilation
- Efficient utilisation of low temperature heat



Approach:
- Theoretical analyses
- Modelling, simulation and optimisation
- Laboratory experiments
- Building prototypes
- Testing at industry sites

Industry specific R&D - Cases

Energy efficient industry clusters

Case 1.1 TINE Verdal - Energy saving by hot water tanks.

Case 1.2 Tine Nærbø – Energy sharing - cluster

Case 1.3 Hydro - Electricity from high temp surplus heat.

Case 1.4 Norske Skog - Optimal exploitation from lower temp surplus heat.

Case 1.5 Hydro Sunndal –. Optimization of existing industry cluster.

Supermarkets

Case 2.1 High efficient R744 compressor.

Case 2.2 Multi R744 Ejector system

Case 2.3 Optimal existing Supermarket - Dragvoll:

Optimization of existing supermarkets.

Case 2.4 The Supermarket of tomorrow - Kroppanmarka:

Fully integrated energy concept.

Food industry

-Control of heat pump processes

Case 3.1 RSW on ship

Case 3.2 Clip fish tunnels.

Case 3.3 Freezing tunnels.

Case 3.4 Superchilling vs. traditional – energy/LCA.

Case 3.5 Waste heat utilization in refrigeration

EFFORT KMB

Energy Efficiency in Offshore Oil and Ga Production

- **Funded by:** the Research Council of Norway (65%) and the Industrial partners (35%)
- **Budget:** 27.6 mill NOK
- **Project Duration**: late 2010- 2014

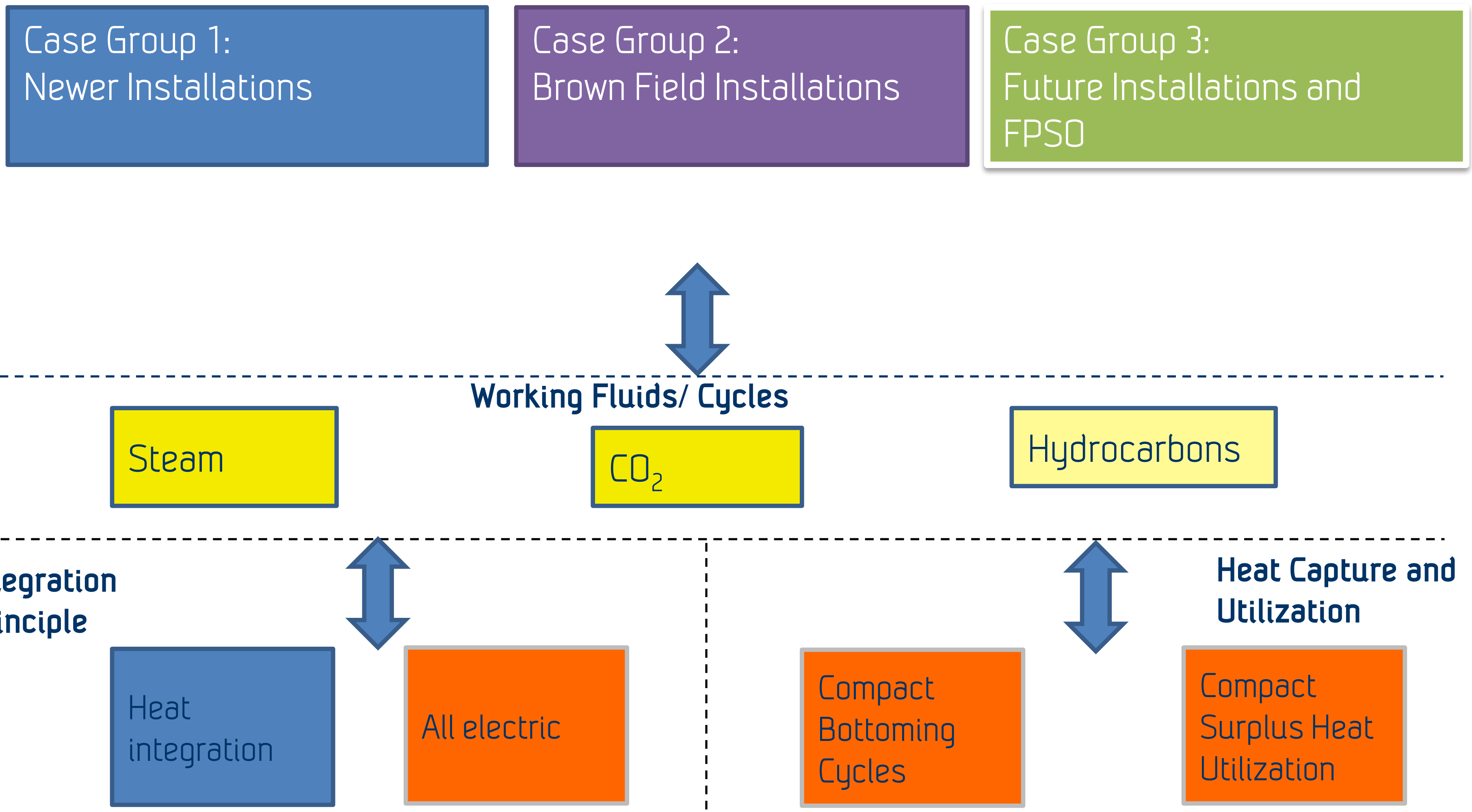
Goal of EFFORT

- Develop **Energy Efficient** technologies and solutions for offshore oil and gas production

- Promote **Implementation** of the technologies offshore

⇨ Reduced Energy Use and CO_2 emissions

EFFORT Case Studies



Expected Outcome & Opportunities

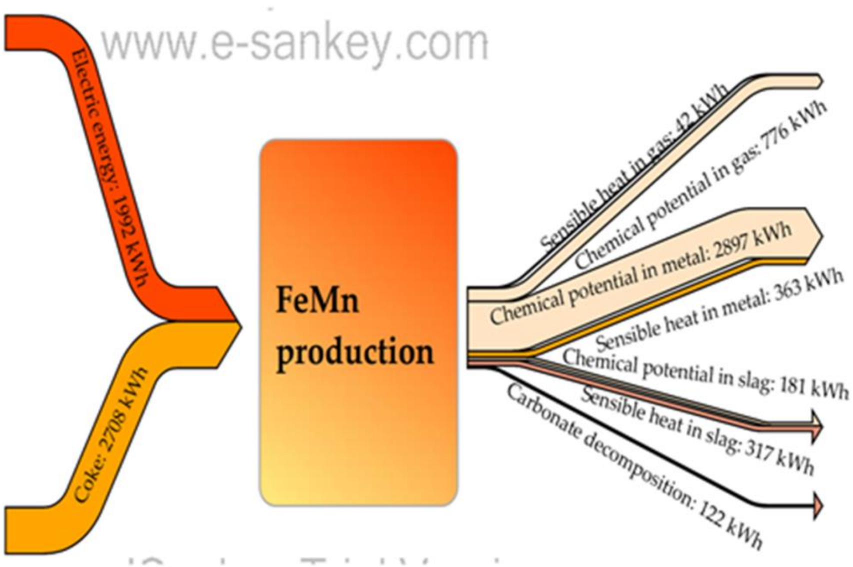
- Enhanced energy efficiency and reduced CO_2 footprint offshore
- **CO_2 reductions up to 50,000 tonnes/year/platform**
- **22-30% reduction in CO_2 emissions**
- Opportunities for implementation of technology and spin-off projects
  - **Demo project with one of the EFFORT industrial partners is underway in DEMO 2000**

ROMA

KPN ROMA

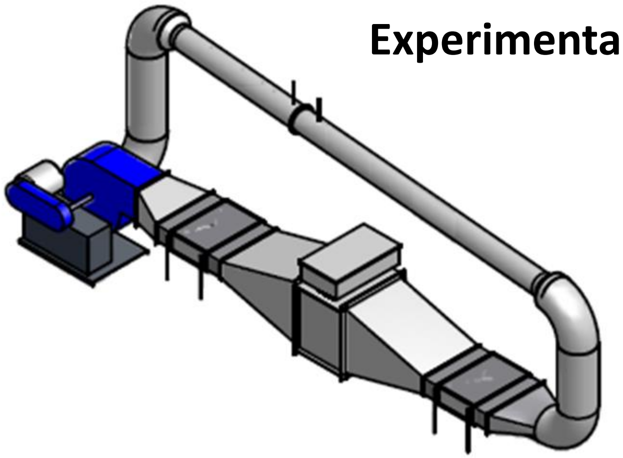
- Energy Mapping
  - Energy mapping for Mn
  - Energy mapping for Al-production

- Energy recovery, waste heat to power production
  - Heat recovery heat exchanger for dirty gas
  - CO_2 transcritical power cycle

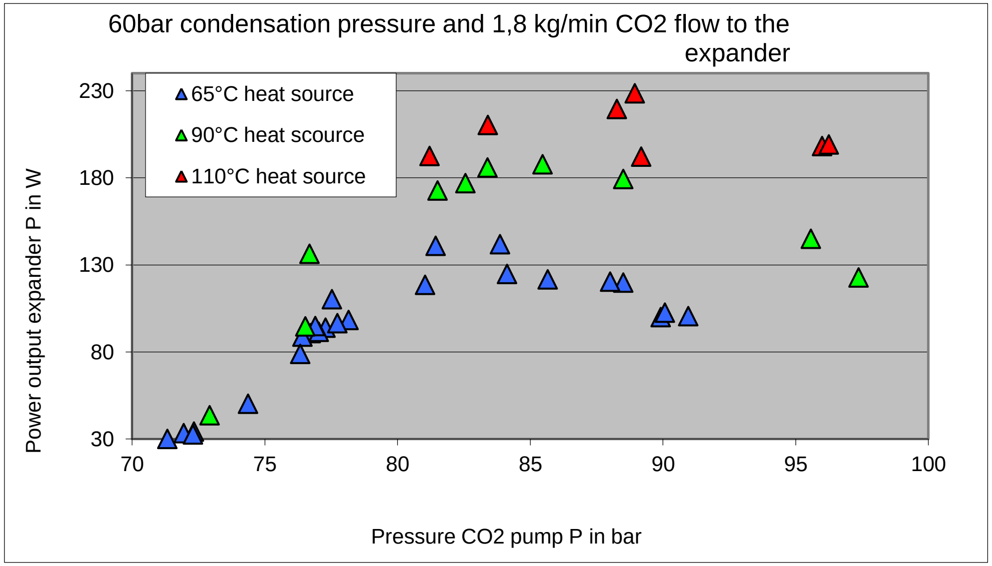


ROMA

- Potential for 20% efficiency improvement
- Power cycle stability proven
- Control strategy established



Experimental test rig

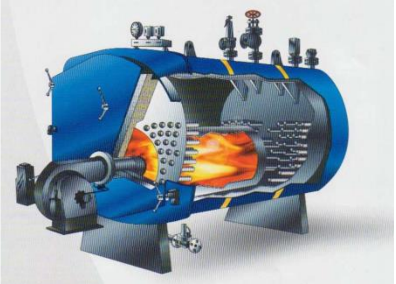


500W prototype turbine

Optilam

- Main goal
  - Develop new, environmentally friendly concept for processing, storage and distribution of fresh lamb; ensuring product quality and prolonging shelf life with 100%
- Subgoal
  - Show a 50% reduction in external energy use for tap water heating by using excess heat from the refrigeration system and a heat pump

ENERGY- AND CARBON FOOTPRINT REDUCTION IN INDUSTRIAL PRODUCTION OF HOT WATER IN ABATTOIR BY USE OF SURPLUS HEAT AND HEAT PUMP SYSTEMS



Steam is often produced by boilers with Oil / Gas / Electricity as energy source.

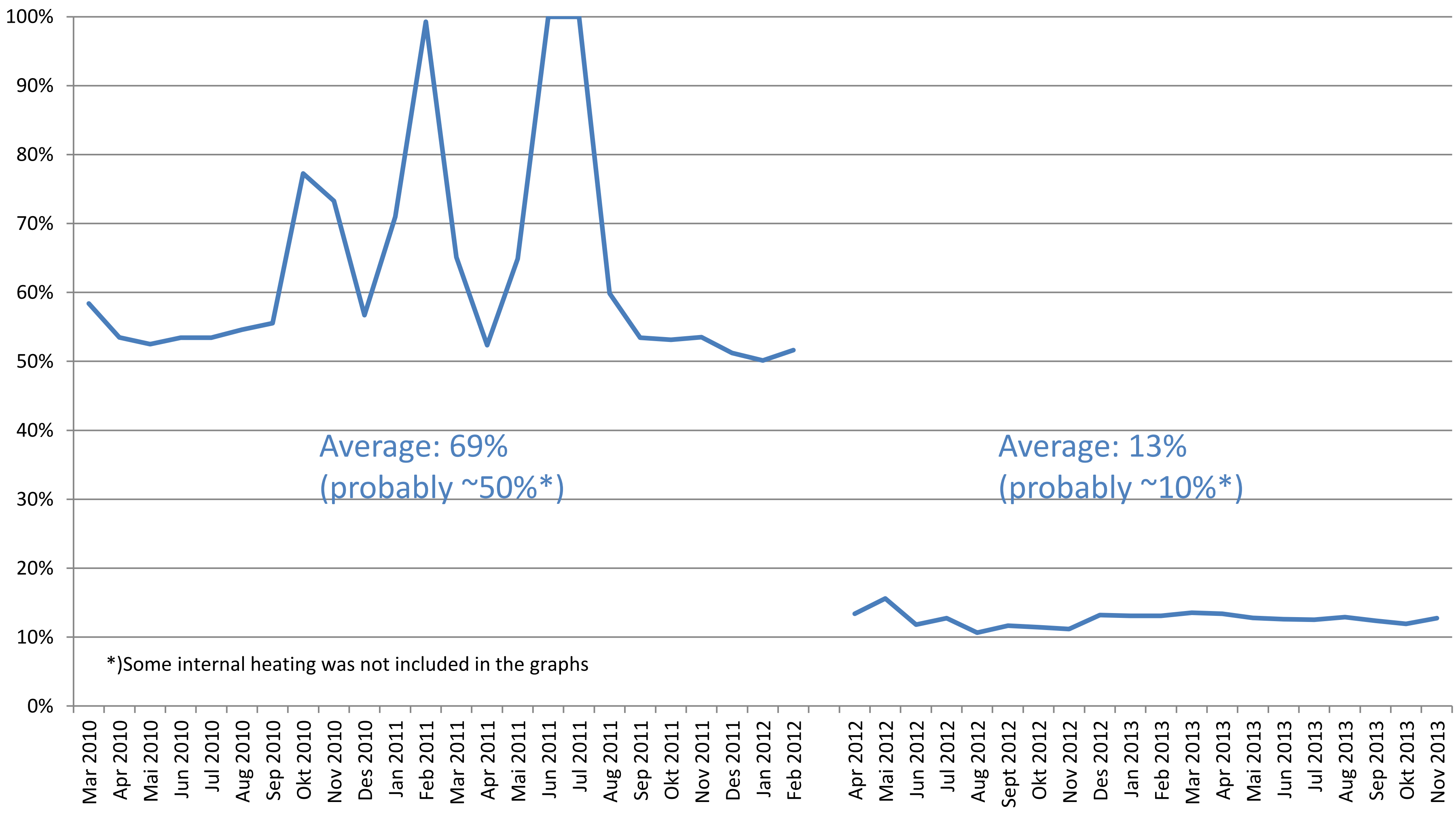
The food industry have normally large refrigeration system where the surplus heat from the compressors and condensers often is let to ambient air.

The low-grade surplus heat can be used directly,

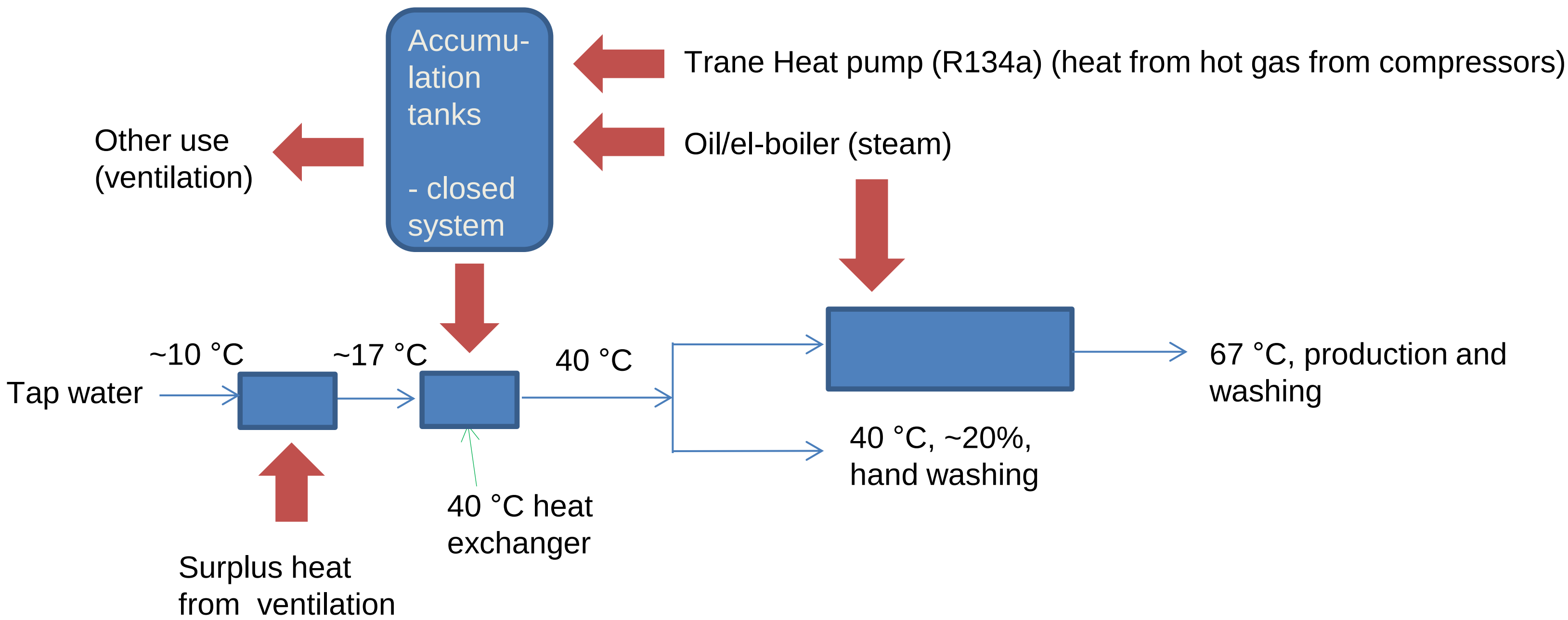
or increased in "value" by us of industrial heat pump systems, where the temperature is lifted.

Some of the external energy used to heat the water (to the boilers) can be substituted with surplus heat from the plants refrigeration system.

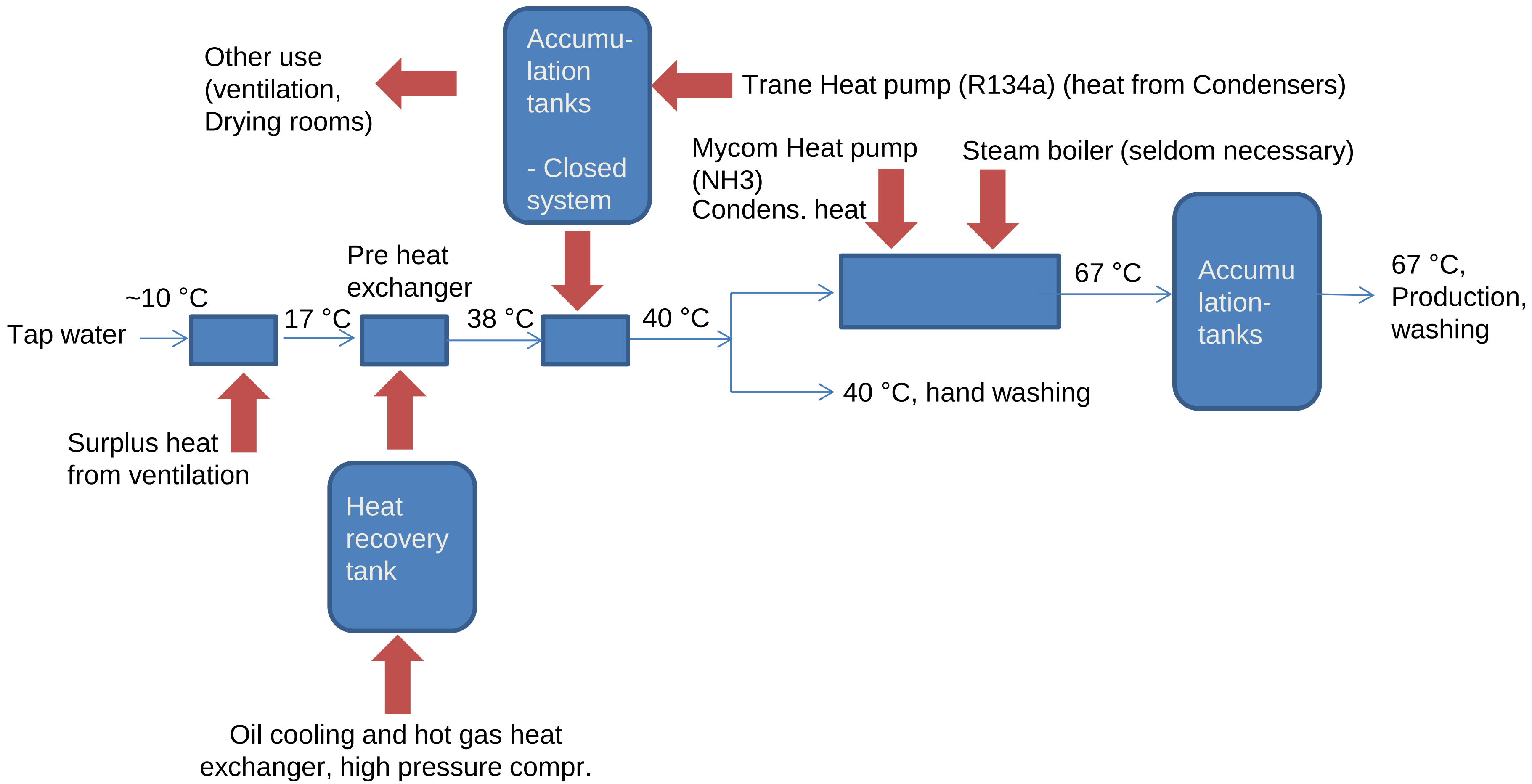
Use of external energy (electricity + oil) for tap water heating



Before Mycom Heat Pump



After Mycom Heat Pump

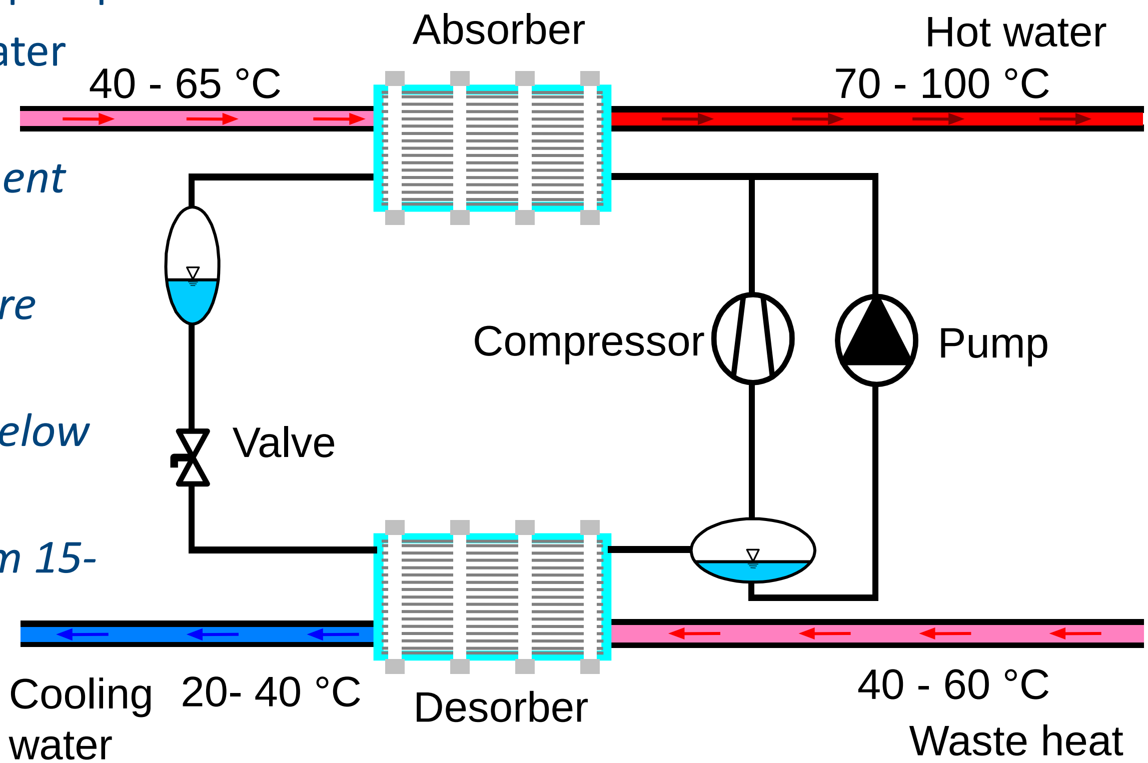


3. Major Demo Projects or Applied Case Studies

- Hybrid Energy – high temperature heat pump with waste heat recovery
- Single Phase power – high temperature heat pump and power generation
- Finnfjord – Waste heat electricity production
- Elkem (Thamshavn, Salten og Bjølvefossen) – Waste heat electricity production

Hybrid Energy – Industrial High-Temperature Heat Pump Systems – Waste Heat Recovery

- Compression / absorption heat pump
  - working fluid: ammonia-water mixture
  - *Built with standard equipment with industry standard*
  - *Delivers heat at temperature level up to 110 °C*
  - *Operates at low pressure below 25 bar*
  - *Recovers waste energy from 15-65°C*



www.hybridenergy.no

Single Phase Power – High Temperature Heat Pump and Power Production from Waste Heat

- **Moelven Eidsvold Værk**
- The prototype at the sawmill Moelven Eidsvold Værk in Eidsvoll, Norway was installed 2009.
- The heat source for the engine was excess steam at about 100°C, and the heat sink was cooling water with a temperature from 4 to 20°C. The prototype was used to test various components of the engine.

- **Hurum Energigjenvinning**
- The first prototype was installed at the waste incineration plant Hurum Energigjenvinning. The prototype was installed in 2007.
- The prototype used steam at 180°C as a heat source and cooling water at 10 to 20°C as the heat sink. The prototype was used to prepare the engine by generating electricity from waste.

www.sppower.no

Finnfjord: Manufacturer of Ferrosilicon – Power Production from Waste Heat

- **Finnfjord AS**
- The most climate efficient producer of ferrosilicon in the world
- Waste heat recovery plant capable of producing up to 340 GWh of electricity
- Reducing energy use of the ferrosilicon process with ~40%
- This investment has considerably increased the attention towards waste heat recovery and its potential in Norway

www.finnsnesindustripark.no

Elkem (Thamshavn, Salten og Bjølvefossen) – Waste Heat Electricity Production

- Elkem Salten has an annual production of 70.000 tonne silicon, 32.000 tonne Microsilica and 8.000 tonne Sidistar (2011)
- Power consumption 1 TWh/year
- Enova has promised 40 million € for waste heat recovery at Salten
- Waste heat recovery plant will produce 300 GWh of electricity

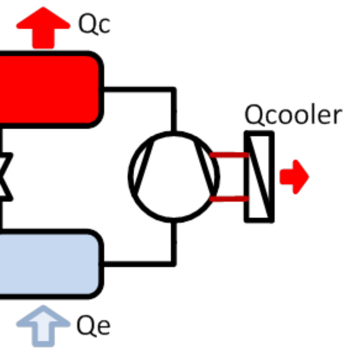
http://www.tu.no/kraft/2012/11/19/elkem-salten-skal-gjenvinne-spillvarme

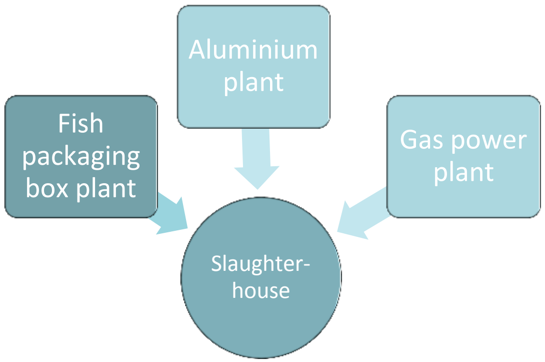
4. Examples of Norwegian Case Studies

- Seafood Industry- Salmon Slaugtherhouse
- Metals Industry- Aluminium Plant delivering district heat
- REMA Supermarket waste heat recovery and reuse in store

Salmon slaughterhouse
Waste Heat Sources

- Internal
  - Heat from refrigerating machine compressor oil cooling
- External (neighboring plants)
  - Fish packaging box production plant
  - Aluminum production plant
  - Gas power plant

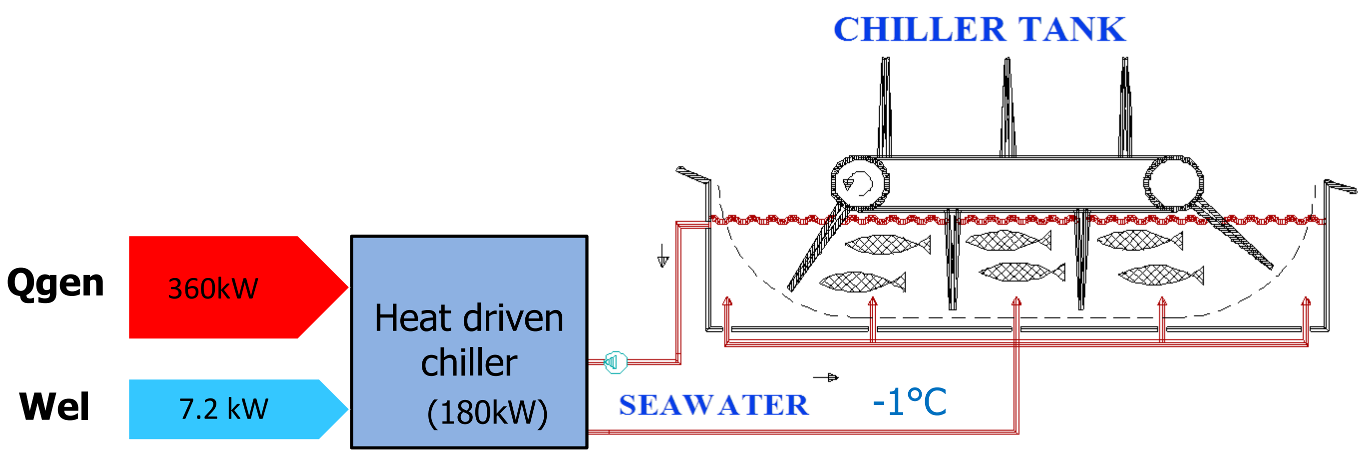




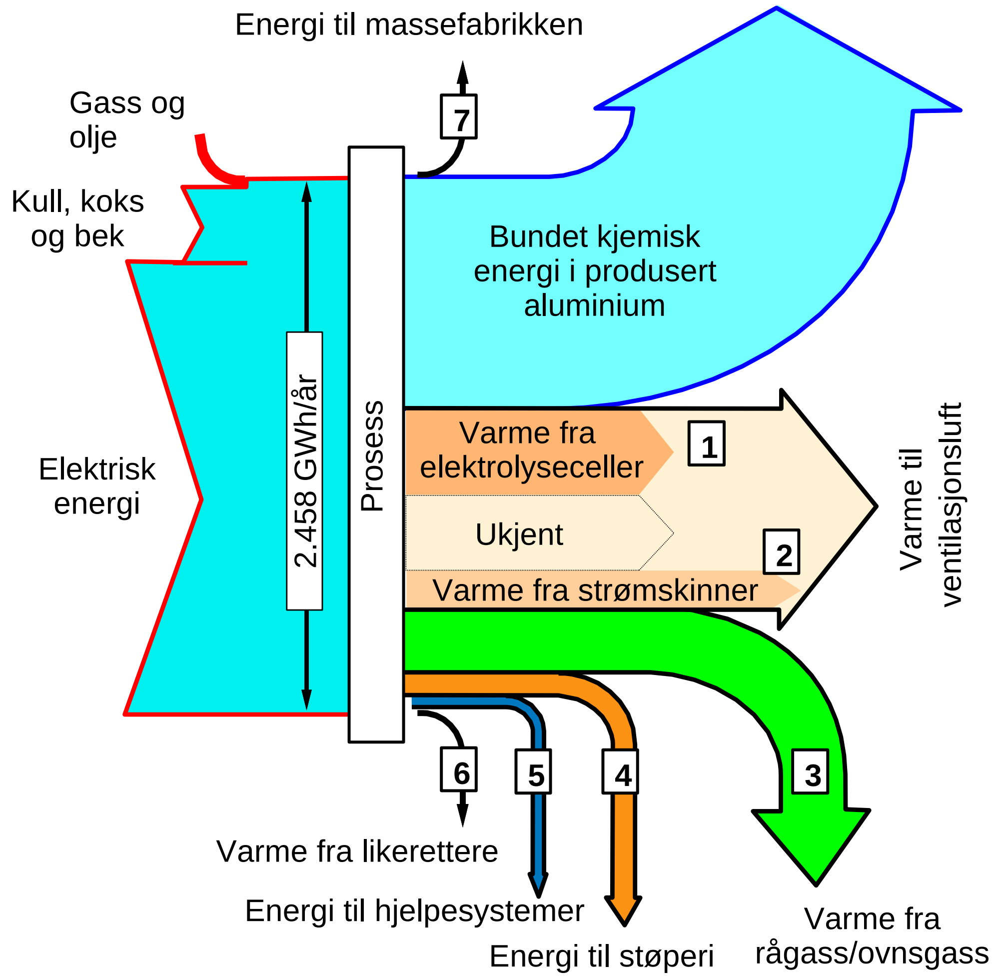
Case study

Use of a heat driven chiller to cover the chilling demand in a salmon slaughterhouse

- Cooling coefficient of performance, COPc = 0.5
- Electricity demand approximately 4% of rated chilling power = 7.2kW (16.67 MWh per year)
- Heat demand to drive absorption chiller = 360 kW



Energy from aluminium plant



Energy Exiting Plant- GWh/år

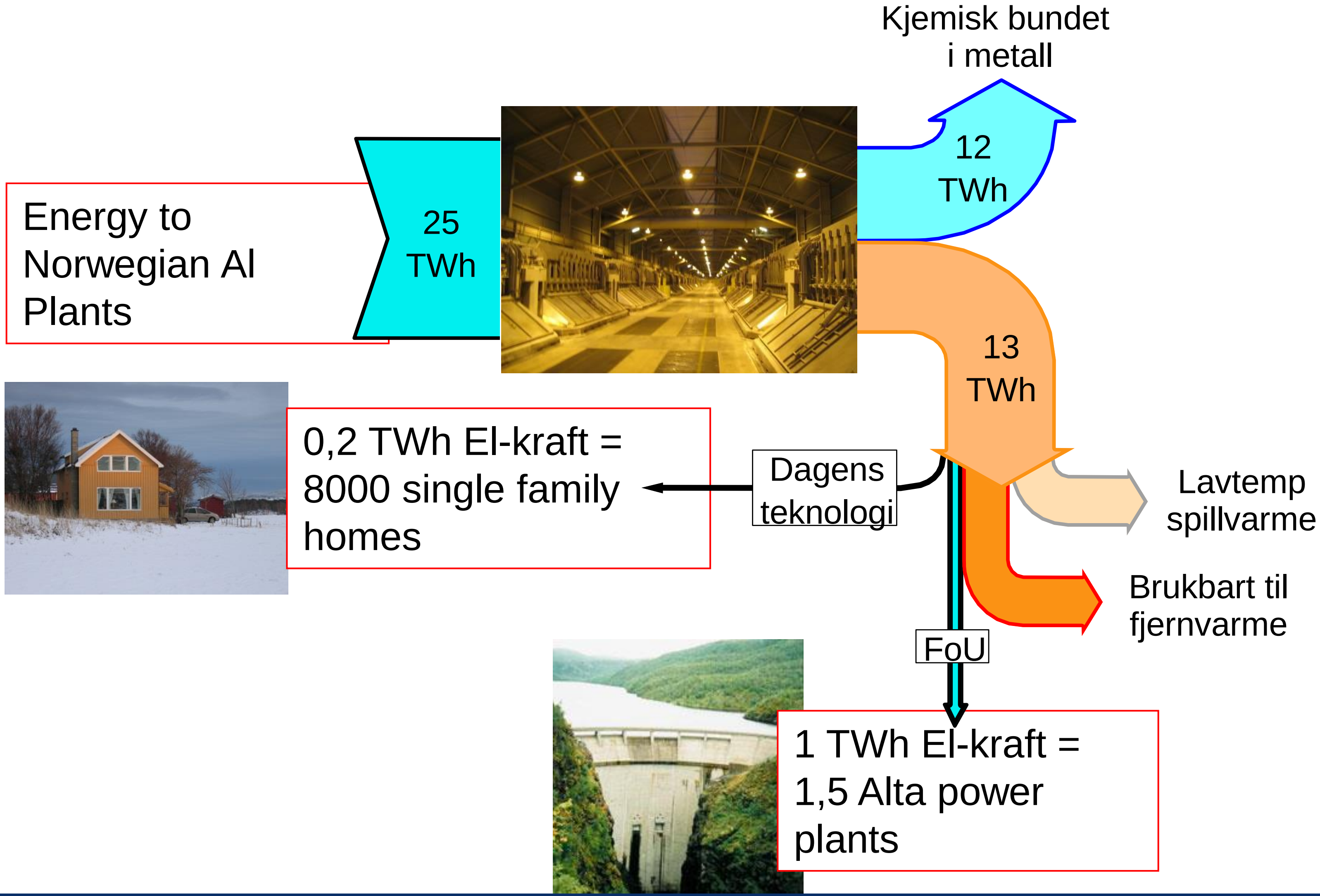
■	Chemically bound	1115
1.	Waste Heat Cells	~ 400
2.	Power supply lines	~ 160
3.	Cell fumes	~ 400
4.	Energy to Cast Plant	~ 90
5.	Support systems	~ 65
6.	Equalizer loss	~ 30
7.	Energy for Anode plant	~ 3
	Unknow	195

	Sum ut	2.458

HSk 2007-06-12

Industrypark

Potensials



Present and Future Supermarket

1. Light Control System- aerogel lets daylight into store
2. Waste Heat from Cooling intermediately stored in water tanks and heat distributed back into the store through ventilation system and floor& heating as needed

Direction of Ongoing and Future Research

- Waste heat recovery for internal use in food industry
    - Drying, process pre-heating, tap water pre-heating, heating of buildings
    - Fish processing
    - Supermarkets

- Industrial Waste Heat Integration- clusters of businesses
    - Aluninium, Cement

- Offshore & Shipping and other Transportation

- Storage of Waste Heat
    - Example: Waste Heat from Garbage Incineration storage in summer for use in winter
    - Flexibility in Power Generation- Integration with Renewables

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