

# HEARTLAND ENERGY MAPPING STUDY

## COMMUNITY INTEGRATED ENERGY MAPPING FEASIBILITY STUDY IN ALBERTA'S INDUSTRIAL HEARTLAND AND STRATHCONA INDUSTRIAL AREA

- NOVEMBER 2014 -



FUNDED BY



National Resources  
Canada

Ressources naturelles  
Canada

EXECUTIVE SUMMARY.....	5
1 ACKNOWLEDGEMENTS.....	9
2 PROJECT TEAM.....	10
2.1 C3.....	10
2.2 CMC RESEARCH INSTITUTES.....	10
2.3 ALBERTA INNOVATES TECHNOLOGY FUTURES.....	10
2.4 ALBERTA'S INDUSTRIAL HEARTLAND ASSOCIATION .....	10
3 INTRODUCTION.....	11
3.1 PROJECT GOALS .....	13
4 OVERVIEW OF STUDY METHODOLOGY.....	14
4.1 PROJECT LOCATION .....	14
4.2 COMPANY SELECTION AND ENGAGEMENT .....	15
4.3 REVIEW OF OTHER INDUSTRIAL PARKS.....	17
4.4 DATA CAPTURE AND ANALYSIS .....	19
4.4.1 EXHAUST STACKS.....	21
4.4.2 COOLERS AND COMPRESSORS.....	22
5 RESULTS .....	24
5.1 LOW POLLUTANT EXHAUST STACKS – SENSIBLE WASTE HEAT FROM COOLING TO 120 °C	26
5.2 COOLERS AND COMPRESSORS .....	28
5.3 LETDOWN OF PRESSURIZED STREAMS .....	31
5.4 SUMMARY OF MESSAGES HEARD FROM COMPANIES .....	32
5.5 COMPONENTS NEEDED TO ACHIEVE ENERGY INTEGRATION .....	34
6 HIGH-LEVEL EXPLORATION OF OPTIONS.....	36
6.1 OVERVIEW OF WASTE HEAT RECOVERY .....	36
6.2 TECHNICAL AND ECONOMIC LIMITATIONS TO WASTE HEAT RECOVERY.....	37
6.3 IDENTIFICATION AND EXPLORATION OF OPTIONS.....	39
6.3.1 POTENTIAL OPPORTUNITIES ACROSS ALL WASTE ENERGY ISLANDS .....	39
6.3.2 STRATHCONA INDUSTRIAL AREA.....	40
6.3.3 HEARTLAND NEAR FT. SASKATCHEWAN.....	41
6.3.4 HEARTLAND NEAR SCOTFORD .....	41

7	CONCLUSIONS AND RECOMMENDATIONS .....	43
7.1	CONCLUSIONS.....	43
7.2	RECOMMENDATIONS.....	44
8	CLOSING .....	46
9	APPENDIX: PROJECT BACKGROUND .....	48
9.1	PROJECT HISTORY .....	48
9.2	PROJECT OVERVIEW .....	49
10	APPENDIX: STAKEHOLDER ENGAGEMENT.....	51
10.1	OUTREACH.....	51
10.2	INDUSTRY KICK OFF MEETING SUMMARY .....	52
11	APPENDIX: DATA TEMPLATES .....	55
11.1	DATA CAPTURE TEMPLATES.....	55
11.1.1	<i>ENERGY INPUTS.....</i>	<i>55</i>
11.1.2	<i>EXHAUST STACKS.....</i>	<i>55</i>
11.1.3	<i>COOLERS.....</i>	<i>56</i>
11.1.4	<i>COMPRESSORS.....</i>	<i>56</i>
11.2	CALCULATION OF WASTE ENERGIES .....	57
11.2.1	<i>GENERAL EXHAUST GAS .....</i>	<i>57</i>
11.2.2	<i>GAS TURBINES.....</i>	<i>58</i>
11.2.3	<i>PETCOKE PYROLYSIS.....</i>	<i>59</i>
11.2.4	<i>SITES PROVIDING NATURAL GAS FLOW RATES.....</i>	<i>60</i>
11.2.5	<i>ADDITIONAL RESULTS - LOW POLLUTANT EXHAUST STACKS, LATENT AND SENSIBLE HEAT (COOLING FROM 120 TO 40 °C).....</i>	<i>61</i>
11.2.6	<i>ADDITIONAL RESULTS - HIGH POLLUTANT EXHAUST STACKS – SENSIBLE HEAT (COOLING TO 120 °C).....</i>	<i>64</i>
12	APPENDIX: REVIEW OF OTHER INDUSTRIAL PARKS RESULTS.....	68
12.1	CASE STUDIES: EXAMINATION OF BEST PRACTICES.....	68
12.1.1	<i>GOTEBORG ENERGI DISTRICT ENERGY SYSTEM.....</i>	<i>68</i>
12.1.2	<i>PROPOSED WASTE HEAT RECOVERY/DISTRICT HEATING PROJECT AT THE PORT OF ANTWERP, BELGIUM.....</i>	<i>72</i>
12.1.3	<i>INDUSTRIAL COGENERATION PROJECTS IN SARNIA-LAMBTON, ONTARIO.....</i>	<i>76</i>
12.1.4	<i>SHELL SCOTFORD MANUFACTURING IN ALBERTA’S INDUSTRIAL HEARTLAND....</i>	<i>81</i>
13	APPENDIX: REVIEW OF HEAT CAPTURE TECHNOLOGIES .....	87

13.1	RANKINE CYCLE (STEAM TURBINE) .....	87
13.2	ORGANIC RANKINE CYCLE (ORC).....	87
13.3	KALINA CYCLE.....	88
13.4	STIRLING ENGINES .....	89
13.5	THERMOELECTRIC.....	90
13.6	NON-CONDENSING & CONDENSING HEAT EXCHANGERS.....	90
13.7	TRANSPORT MEMBRANE CONDENSER.....	92
13.8	HEAT PIPES .....	92
13.9	TEMPERATURE UPGRADE: HEAT PUMP .....	93
13.10	TEMPERATURE UPGRADE: STEAM RECOMPRESSION.....	93
13.11	HEAT TO COOLING .....	93
14	APPENDIX: FEEDBACK FROM EXPERT REVIEWERS.....	95
14.1	EXPERT REVIEW PANEL.....	95

# EXECUTIVE SUMMARY

---

The Community Integrated Energy Mapping Feasibility Study obtained data from 16 companies (17 industrial sites) in the Strathcona and Heartland Industrial Areas near Edmonton, Alberta to understand the energy flows and associated waste energy within these regions. An understanding of the energy types, amounts, qualities, temporal variability and geographic constraints of this energy is essential for the development and implementation of a business case for regional energy integration solutions.

The need for Canada (and Alberta) to find and exploit all efficiency opportunities is highlighted by a recent US National Academy of Sciences report<sup>1</sup> which noted that Canada's energy use per dollar of GDP is ~1.5 times higher than that of the US, and ~two times higher than Japan, Germany, and the UK. To remain competitive, Canada must become more energy efficient. Becoming more energy efficient will reduce Alberta's greenhouse gas (GHG) emissions, which has an environmental benefit while also improving industry productivity and competitiveness, thereby creating more vibrant Alberta communities.

The project team, which includes C3 (formerly Climate Change Central), Alberta Innovates Technology Futures (AITF) and the Alberta Industrial Heartland Association (AIHA), focused the study on the Heartland and Strathcona Industrial Areas. With the closing of C3, CMC Research Institutes has now assumed leadership for energy mapping in Alberta, Canada and internationally. The Heartland region, northeast of Edmonton, Alberta includes five municipal districts while the Strathcona Industrial Area is situated between Edmonton and Sherwood Park. Both industrial areas are home to approximately 60 companies in total across a variety of sectors primarily producing and processing oil, gas, and petrochemicals, as well as advanced manufacturing. Over the past several decades, these areas have grown into Canada's largest hydrocarbon processing region.

Companies that participated in the study include Agrium, Air Liquide, Air Products, AltaSteel, ATCO Energy Solutions, Keyera Energy, North West Redwater Partnership, Oerlikon Metco (Canada) Inc., Plains Midstream, Rio Tinto Alcan, Shell Canada, Sherritt, Suncor Energy, Umicore, Veresen and Western Hydrogen. The wide industrial mix and proximity to municipalities helps to ensure that the methods developed in this region can be applied to other industrial parks and regions across Canada.

Project funding was provided by Natural Resources Canada and the Alberta Industrial Heartland Association.

Between May 2013 and June 2014, the project team: secured sufficient industry stakeholder participation from the ~60 companies in the two industrial areas; secured access to appropriate data on energy supply and demand from participating companies; reviewed similar industrial parks around the world; reviewed heat capture and re-use technologies; and identified the opportunities and high-level barriers to using the waste heat streams identified through this study.

While this is the first regional industrial energy mapping study completed in Canada, energy mapping is done in other parts of the world. A global review of industrial parks demonstrated that three critical factors must be present for industry to begin pursuing greater industrial integration and symbiosis:

---

<sup>1</sup> National Academies Press, 2010. "Real Prospects for Energy Efficiency in the United States", Figure 1.1.1, [http://www.nap.edu/catalog.php?record\\_id=12621](http://www.nap.edu/catalog.php?record_id=12621)

1. **A convincing business case must exist** that indicates ways to reduce costs or generate new revenue, and that these actions can actually be undertaken by local businesses;
2. **The social license to achieve efficiencies exists**, meaning that the policy or regulatory barriers to achieving efficiencies can be overcome, and communities potentially affected by the initiative endorse the activities;
3. **The use of proven technology** to enable resource synergies must exist and have been proven to work (i.e., low implementation risk).

The study revealed a significant amount of waste heat exists in the Strathcona and Heartland industrial areas. Geographically, the waste heat was clustered into three heat islands (see Figure 1) across the two industrial areas. These geographic limitations have implications for the feasibility of using the waste energy on a regional basis. While the results contain many subtleties described in the full report and Appendix, the study identified:

- 300 MW of sensible waste energy, of which:
  - 64 MW comes from low pollutant exhaust stacks with temperatures between 230 and 1100 °C;
  - 85 MW comes from low pollutant exhaust stacks with temperatures between 120 to 230 °C;
  - 151 MW comes from coolers and compressors with temperatures between 80 and 230 °C.

It should be stressed that these results are only for the 17 participating sites. Other companies known to have significant amounts of waste heat did not participate in the study. Further, not all participating companies reported on all of their major waste heat streams (e.g., a few only reported on exhaust stacks, but not cooling towers). Finally, lower temperature cooling streams between 20 and 80 °C have been excluded due to the inherent challenges of repurposing such low temperature heat. Thus, the results above are conservative relative to the actual waste energy available in these industrial areas.

For each heat island, assuming that 33% of this total available waste energy could be captured and repurposed, the resulting 99 MW of waste energy could theoretically be used to:

- Heat 15,200 average homes<sup>2</sup>;
- Generate 5 MW of power - enough to power 5,100 homes<sup>3</sup>;
- Reduce CO<sub>2</sub>e emissions in the region by ~151,000 tonnes<sup>4</sup>.

---

2 Assuming that heating a house requires 160 GJ of natural gas.

3 That 20-30% of the waste energy (depending on temperature) could be converted to power, and that a house requires 7,800 kWh of power a year.

4 Based on NRCAN emission reduction factors (<http://www.nrcan.gc.ca/energy/efficiency/industry/technical-info/benchmarking/canadian-steel-industry/5193>).

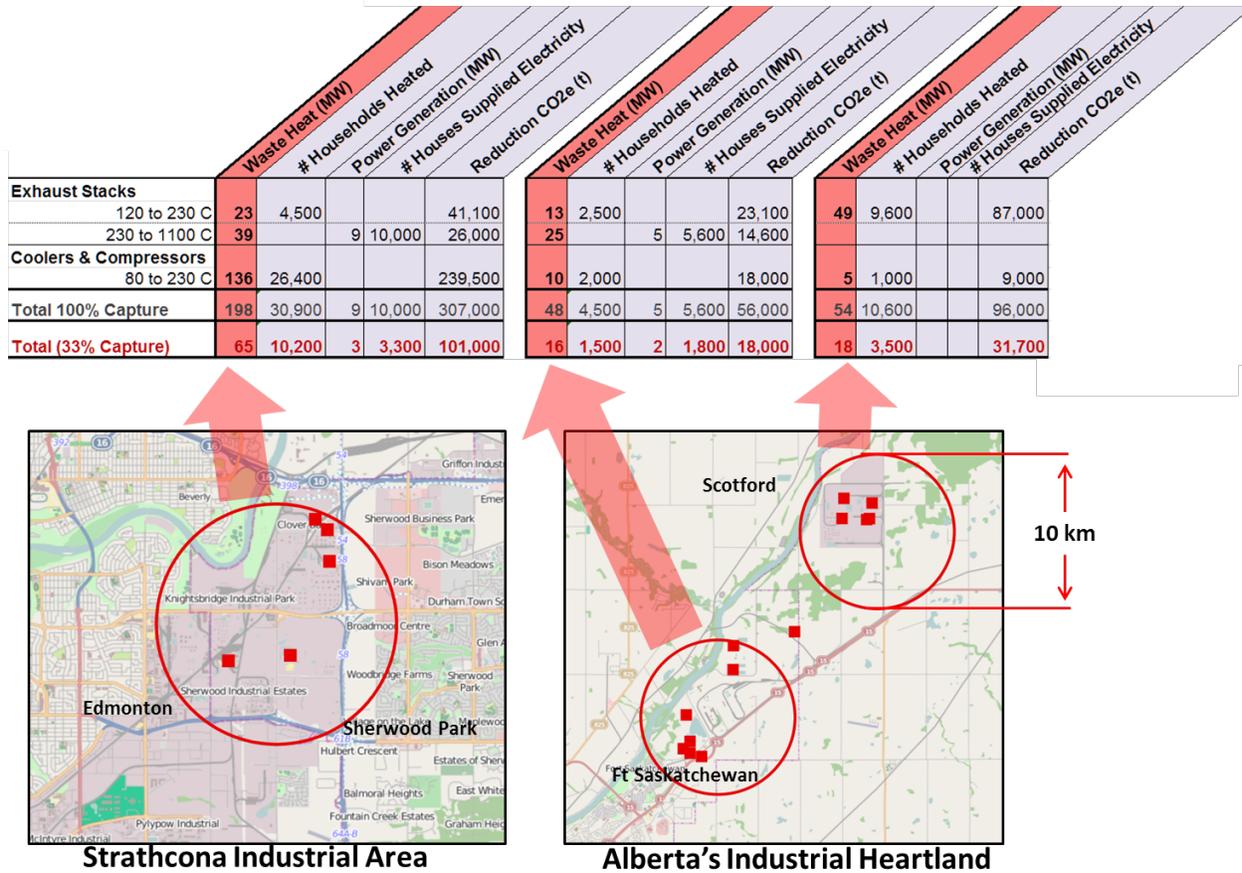


Figure A: Aggregate summary of the amount of potentially recoverable waste heat from exhaust stacks and coolers and compressors across the heat islands identified in the two industrial areas. Energy sources which had high levels of pollutants or other associated risks are NOT included in this summary. The diameter of each red circle is 10 km.

Given the significant amounts of waste heat available, there are a number of opportunities within these energy islands that warrant further investigation and should be considered in the future. These include:

- **Electricity generation from waste heat streams** by routing the mid-grade waste heat identified in this study to technologies such as Organic Rankine or Kalina Cycle systems.
- **Natural gas pressure letdowns** that result from the large amounts of natural gas consumed in each of these industrial areas could be used to generate electricity.
- **High temperature energy sources** identified could be sufficient to support the installation of third-party operated power generation systems on selected sites.
- **Regional Steam Utilities** should be explored as a way to increase the overall level of steam security on industrial sites, making it less likely that an interruption in steam supply would trigger a site shutdown. Such utilities could incorporate COGEN and such a utility would also lower the capital costs associated with developing new industrial sites in the region.
- **Heating of intermediate product tanks** by using waste heat from primary operations.

- **Redevelopment opportunities within sites and between sites** represent a significant opportunity for COGEN and possibly even ‘sub-regional’ steam systems if ways can be found to locate other industrial sites close to these plants.
- **District heating systems in neighbouring communities** are presently challenging given the large distances between the heat sources and neighbouring municipal development; and given that some of the surrounding municipal development is low-density, single-family houses. Further collaboration with municipalities neighbouring these industrial areas is needed to drive future development with the characteristics needed to take advantage of the identified energy resource.

The knowledge generated by this regional industrial energy mapping study suggests a number of key recommendations, which are critical to developing an implementation plan that would achieve meaningful results:

**Create an “Industrial Cluster Management System” (ICMS)** to address the policy, regulatory, and social barriers inhibiting energy integration in these industrial regions. The goal of the ICMS would be to engage and coordinate the multiple players (industry, provincial and municipal governments), which need to be involved to advance Alberta’s development of industrial areas. The creation of such a system would be a natural next step given the review of eco-industrial policy barriers currently being conducted by Innovation and Advanced Education. The ICMS would:

1. Include an independent, third party intermediary to potentially facilitate the creation of shared infrastructure, coordinate infrastructure planning and development, identify opportunities for third party service providers, and identify ways to increase the attractiveness of the industrial areas to investors.
2. Identify and find ways to address the major social and technical innovation barriers facing the industrial areas such as removing risks associated with greater industrial integration, or finding ways to reduce the risks to companies for implementing new technologies.
3. Evaluate business cases and operational models for such opportunities as regional utilities (e.g., steam or water).
4. Engage with surrounding municipalities.

**Publicize the results of the study** across industrial, commercial, and manufacturing and government sectors

**Scale the work** to other industrial areas in Alberta and the rest of Canada.

In conclusion, the results of the Community Integrated Energy Mapping Feasibility study indicate a positive value proposition for further industry and government engagement for implementation actions that reduce GHG emissions, improve competitiveness, enhance efficiency and contribute to economic diversification.

# 1 ACKNOWLEDGEMENTS

---

The project team would like to acknowledge the generous financial support provided by Natural Resources Canada and the Alberta Industrial Heartland Association.

C3 is also grateful to its project partners, Alberta Innovates Technology Futures (AITF) and Alberta's Industrial Heartland Association (AIHA).

In addition, the project team would like to acknowledge the companies that participated in this project, which included:



## 2 PROJECT TEAM

---

### 2.1 C3

C3 (formerly Climate Change Central) was an Alberta-based non-profit that encouraged energy efficiency and the small-scale use of alternative energy sources by Albertans. C3 engaged decision-makers – individuals, businesses and other organizations – to encourage new choices about energy use. C3 partnered with government, municipalities and corporations to design and administer tailored programs to help people use less energy, save money, and reduce GHG emissions. Based in Calgary and with an office in Edmonton, C3 staff included economists, policy analysts, program managers, web developers, accountants and communicators – each staff member brought specific experience and expertise to every project C3 engaged. C3 was the team lead on the Community Integrated Energy Mapping Feasibility Study.

### 2.2 CMC RESEARCH INSTITUTES

CMC Research Institutes is an independent, not-for-profit business working to develop multiple, challenge-driven research institutes focused on providing high-value, low-barrier research and development services to industry or public sector clients addressing the challenge of industrial greenhouse gas emissions. CMC will be assuming leadership for energy mapping initiatives in Alberta, across Canada and internationally ([www.cmcghg.com](http://www.cmcghg.com)).

### 2.3 ALBERTA INNOVATES TECHNOLOGY FUTURES

AITF's business is to build globally competitive commerce in Alberta by facilitating the commercial use of new technologies, developing new knowledge-based industry clusters, and encouraging an entrepreneurial culture in Alberta. AITF is part of Alberta's research and innovation system. Through a suite of programs and services directed towards entrepreneurs, companies, researchers and investors, AITF is preparing Alberta for a next generation economy and offers a suite of technical expertise, funding programs, and accessible commercialization support ([www.albertatechfutures.ca](http://www.albertatechfutures.ca)).

### 2.4 ALBERTA'S INDUSTRIAL HEARTLAND ASSOCIATION

Alberta's Industrial Heartland is guided by a non-profit association of municipalities dedicated to sustainable eco-industrial development. Alberta's Industrial Heartland Association (AIHA) was created in 1998 by the municipalities that each had heavy industrial land within the geographic area of Alberta's Industrial Heartland. A leading principle of AIHA is promoting responsible development within the region ([www.industrialheartland.com](http://www.industrialheartland.com)).

#### **Alberta's Industrial Heartland Association strives to:**

- Provide a single approach to promote and facilitate industrial development by proactively and efficiently collaborating on facilitating services and infrastructure while minimizing land-use conflicts;
- Promote open communication and harmony among participating municipalities and interested parties by providing opportunities for stakeholders to participate in planning and development discussions.

### 3 INTRODUCTION

---

Industrial energy mapping is about quantifying the energy flows within a region in terms of types, amounts, qualities, and temporal variability for the purpose of identifying potential uses for this energy resource. The benefits of this type of energy mapping come from trying to uncover regional energy integration opportunities while characterizing the geographic constraints which must inform the development of a business case for using this energy in any type of regional energy integration solution.

Energy mapping has been identified by many organizations and governments (including CANMET, the Cities of Edmonton<sup>5</sup> and Calgary<sup>6</sup>, etc.) as a process for enhancing planning support, establishing new capacities to simultaneously address energy and environmental issues, enabling energy market transformation, and revealing regulatory barriers which are hindering improvement in energy efficiency. Many Alberta communities have produced Municipal Sustainability Plans and are looking to use tools like energy mapping to inform the delivery of these plans. Provincial and national levels of government are also getting involved in energy mapping. For example, Ontario's *Integrated Energy Mapping for Ontario Communities*<sup>7</sup> initiative supports the development of community energy plans using energy mapping approaches; while the countries of Germany, Austria and Switzerland have undertaken energy mapping initiatives to identify available renewable energy sources and the potential for district energy systems.

Industrial energy mapping is particularly important for Canada given that Canada's energy use per dollar of GDP is about 1.5 times higher than that of the US, and almost two times higher than Japan, Germany, and the UK<sup>8</sup>. To remain competitive over the next 20 years – a time in which IBM's Institute for Business Value<sup>9</sup> predicts that eco-efficiency will be the biggest economic game-changer for organizations – Canada must become more energy efficient. Beyond improving productivity and competitiveness globally, becoming more energy efficient will also help to reduce Canada's GHG emissions.

In Alberta, ~75% of all provincial natural gas consumption is the result of industrial activity<sup>10</sup> and ~70% of Alberta's total GHG emissions are the result such industrial activity<sup>11</sup>. A recent report by the Canadian

---

5 The Way we Green: White Paper, City of Edmonton, 2010. Prepared by the Way We Green Project Team p. 80.  
[http://www.edmonton.ca/city\\_government/documents/WayWeGreenDiscussionPaperOct2010.pdf](http://www.edmonton.ca/city_government/documents/WayWeGreenDiscussionPaperOct2010.pdf)

6 Energy Mapping Study, City of Calgary, 2008. Prepared by the Canadian Urban Institute:  
[http://www.calgary.ca/docgallery/BU/planning/PDF/plan\\_it/energy\\_mapping\\_study.pdf](http://www.calgary.ca/docgallery/BU/planning/PDF/plan_it/energy_mapping_study.pdf) or call Calgary 311 for details

7 <http://questcanada.org/sites/default/files/files/The%20Primer%20-%20reduced%20size.pdf>

8 National Academies Press, 2010. "Real Prospects for Energy Efficiency in the United States", Figure 1.1.1,  
[http://www.nap.edu/catalog.php?record\\_id=12621](http://www.nap.edu/catalog.php?record_id=12621)

9 IBM 2010. "The Emergence of the eco-efficient economy". <http://www-935.ibm.com/services/us/qbs/bus/html/ibv-eco-efficiency-jam.html>

10 <http://www.energy.alberta.ca/NaturalGas/Gas.asp>; <http://www.energy.alberta.ca/NaturalGas/723.asp>

11 National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada. Environment Canada.  
[http://unfccc.int/files/national\\_reports/annex\\_i\\_ghg\\_inventories/national\\_inventories\\_submissions/application/zip/can-2013-nir-15apr.zip](http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2013-nir-15apr.zip)

Manufacturers & Exporters – Alberta Division<sup>12</sup> found for the four manufacturing sub-sectors they examined (which accounted for ~85% of Alberta’s industrial energy use), 74% of their energy consumption was for direct and indirect process heating. Although this study did not explore the potential of regional energy efficiency gains through techniques like energy cascading, the high percentage of process heating uncovered in this study suggests such opportunities likely exist.

However, while a large amount of low-quality waste heat likely exists in Alberta’s industrial areas, the information on energy type, quantity, and quality of energy supply and demand needed to identify regional efficiency and renewable energy opportunities do not exist. The lack of such information on the geographic location, availability of, and demand for, “non-conventional” energy sources means that it is very challenging to identify viable opportunities to use such forms of energy.

Large opportunities for regional industrial energy efficiencies (multi-site industrial collaborations) have been demonstrated internationally. The optimization of energy utilization in an eco-industrial park in Yeosu, South Korea showed potential to reduce total energy costs by more than 88% from base values by using energy cascading (meaning that energy such as steam or hot water from one plant is used by other plants that in turn pass their “waste energy” on to yet other plants)<sup>13</sup>. Similarly, analysis of three industrial parks in Japan showed they could reduce total park energy consumption by 24%, 37%, and 71% by exploiting regional efficiencies<sup>14</sup>. In the North Karelia Region of Finland, a study in 2002<sup>15</sup> showed that switching to district heating systems, biofuels, and cogeneration of heat and power could totally eliminate heating related CO<sub>2</sub> emissions. Presently, some 50% of the total heating market in Finland and Denmark is provided by district heating with 80% of this total being from combined heat and power plants.

Industrial energy mapping has the potential to assist Canada in delivering a variety of societal benefits:

### **Environmental**

- Contributes to achieving regional energy efficiencies and reduction of GHG emissions. Enables discussion of how to reduce direct fossil fuel use for heating purposes in communities, and supports implementation of regional energy plans.

### **Economic**

- Improves competitiveness by enabling industry to identify regional energy efficiency opportunities while reducing the costs of identifying potential synergies.

---

12 Canadian Manufacturers & Exporters – Alberta Division. May 2010. “Improving Energy Efficiency for Alberta’s Industrial and Manufacturing Sectors”. [http://www.inefficiency-from-germany.info/ENEFF/Redaktion/DE/Downloads/Publikationen/Zielmarktanalysen/marktanalyse\\_kanada\\_2014\\_industrie.pdf?\\_\\_blob=publicationFile&v=3](http://www.inefficiency-from-germany.info/ENEFF/Redaktion/DE/Downloads/Publikationen/Zielmarktanalysen/marktanalyse_kanada_2014_industrie.pdf?__blob=publicationFile&v=3)

13 Chae, S.H., S.H. Kim et al., 2010, “Optimization of a Waste Heat Utilization Network in an Eco-Industrial Park”, Applied Energy, vol 87, pp 1978-1988.

14 Hayakawa H., Y. Wakazono et al. 1999, “Minimizing Energy Consumption in Industries by Cascade Use of Waste Energy”, IEEE Transaction on Energy Conversion. vol 14, #3, pp. 795-801.

15 Snakin, J-P.A., and J. Korhonen. 2002. “Industrial ecology in the North Karelia Region in Finland – Scenarios for heating energy supply. International Journal of Sustainable Development and World Ecology, vol 9, pp. 9-21. See also [http://en.wikipedia.org/wiki/District\\_heating](http://en.wikipedia.org/wiki/District_heating)

- Facilitates industrial diversification through industry clustering within geographic areas, which have energy resources.
- Enables characterization of common industrial needs in terms of energy technology solutions and the potential market sizes - thereby supporting strategic technology investment decisions by governments and industry.

## Social

- Identifies the information sharing barriers that are preventing identification of regional energy efficiency opportunities.
- Helps facilitate a change in perspective by government policy makers, industry, and the innovation system so energy efficiency is viewed holistically from a regional perspective (i.e., an interdependent system comprised of individual sites), rather than from the perspective of independent sites that happen to be located in a given region.

## 3.1 PROJECT GOALS

- **Capture Relevant Information** - Given that little was known about the regional energy flows in Alberta's major industrial areas, the main goal of this project was to capture site-level information on energy demand (type of energy, fuel source, quality, and quantity), along with waste energy availability (exhaust gases, hot water, steam, etc.) to try and identify potential regional opportunities for energy integration, particularly with regard to waste heat.
- **Make Process Replicable** – As regional industrial energy mapping had not been undertaken before in Canada, the project was designed so that the methods, tools, and frameworks developed could be applied to other industrial areas within Canada.
- **Address the Social Challenges of Industrial Integration by Building Trust** - Past work done by others<sup>16</sup> demonstrates that achieving regional energy efficiencies requires adopting methods and approaches that address the social challenges of regional energy integration. Current understanding is that existing brownfield sites, which successfully transform into eco-industrial parks transition through phases characterized by increasing degrees of social connectedness among firms<sup>17</sup>. The initial focus is on achieving a regional efficiency win-win outcome, then regional learning, and finally becoming a self-sustaining eco-industrial area. Such transformation takes years, and requires the creation of appropriate supporting social infrastructure (i.e., government policy to support such transformations, along with mechanisms to bring about such transformations).

---

<sup>16</sup> E.g., Harris S, 2008. *Mechanisms to Enable Regional Resource Synergies: Facilitating Structures and Operational Arrangements*. Centre of Excellence in Cleaner Production, Bulletin No. 3. Curtin University of Technology, Perth.

<sup>17</sup> E.g., Boons, F., W. Spekkink, and Y. Mouzakitīs (2011). "The Dynamics of Industrial Symbiosis: a Proposal for a Conceptual Framework based on a comprehensive literature review". *Journal of Cleaner Production*, 19, pp 905-911. Baas, L.W., and F. Boons (2004). "An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems". *Journal of Cleaner Production*, 12, 1073-1085.

## 4 OVERVIEW OF STUDY METHODOLOGY

---

The Community Integrated Energy Mapping Feasibility Study obtained information from 16 companies (17 industrial sites) in the Strathcona and Heartland Industrial Areas near Edmonton. The major tasks carried out to achieve this included:

1. **Securing sufficient industry stakeholder participation** from the ~60 companies in the Strathcona and Heartland industrial areas to generate useful results.
2. **Securing access to appropriate data** on energy supply and demand from participating industrial sites, along with confirming high-level information on the major industrial processes occurring on each site.
3. **Validating** the types, quality, quantity, and variability of energy flowing across industrial sites to better understand overall regional energy availability.
4. **Reviewing similar industrial parks around the world** to identify lessons learned and best practices regarding the facilitation of greater regional energy integration.
5. **Completing a technology review** to understand the potential of existing and emerging technology solutions around recovering surplus energy and transferring it between sites or even outside the boundaries of this heavy industrial area to adjacent future light industrial or residential development.
6. **Building trust** among participant companies, local municipalities and other relevant organizations across the greater Heartland region to enable subsequent phases of work to proceed.
7. **Identifying opportunities and high-level barriers** around implementing viable opportunities that would achieve greater regional energy efficiencies.
8. **Laying the groundwork to enable wider adoption** of the knowledge and methods emerging from this project to other regions of Alberta and Canada.

The ways in which these tasks were accomplished is described in greater detail below.

### 4.1 PROJECT LOCATION

Alberta's Industrial Heartland (AIH) and the Strathcona Industrial Area (SIA) (see Figure 1) were the focus of this study. This region is home to over 60 companies that operate across a variety of sectors primarily producing and processing oil, gas, and petrochemicals, as well as advanced manufacturing. Over the past several decades, the region has grown into Canada's largest hydrocarbon processing region and includes a diverse set of industries including: bitumen upgrading, petroleum refining, petrochemicals, plastics, mineral processing, fertilizer production, natural gas processing, pipeline terminals, production of industrial gases, transportation logistics centers (rail and truck), and also supply and service industries to support these other industries.

The wide industrial mix and proximity to municipalities helps to ensure that the energy mapping methods developed in this region can be applied to other industrial parks and regions across Canada. For example, the AIH borders five municipalities (including the cities of Edmonton and Fort Saskatchewan) and is also the site for one of the carbon sequestration projects supported by the Government of Alberta. The SIA lies between Edmonton and Sherwood Park. Both areas were initially estimated to have many 100s of megawatts of waste heat sources, and corporations within these parks are supportive of eco-industrial strategies for achieving sustainable industrial development. Additionally, the municipalities that are connected to these industrial parks are interested in exploring shared heat opportunities and trying to connect the results of this study to their recently adopted regional sustainability plans.

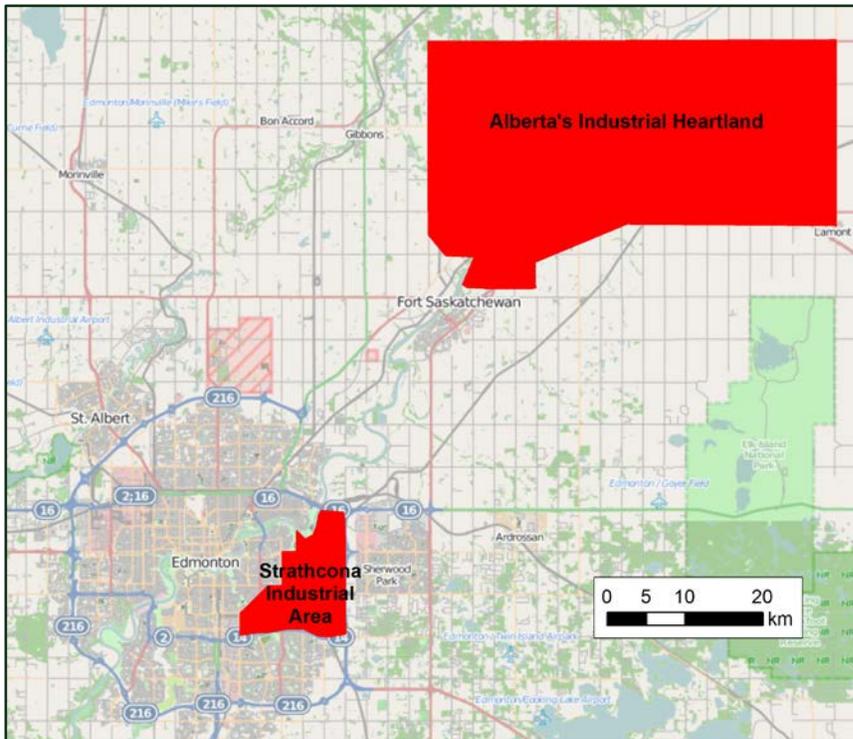


Figure 1: Locations of the Strathcona and Heartland Industrial Areas, which were the focus in this study. It should be noted that the Alberta's Industrial Heartland also includes the Edmonton Energy and Technology Park, which is not shown.

## 4.2 COMPANY SELECTION AND ENGAGEMENT

As this was a feasibility study to demonstrate whether or not significant waste energy exists in these regions, the project team prioritized sites, which were likely to be producing significant amounts of waste energy. Less emphasis was given to identifying sites that could potentially use lower quality waste energy given that the uses for such energy would likely either involve new development or lie on the boundaries of the industrial areas. In total, 16 companies (17 sites) joined the project. The list of all participating companies is included in the Acknowledgements section. Further details are included in the Appendix to this report.

Initial engagement with companies started back in 2011 and during the years between that initial engagement and the start of this project, it was clear to the project team that communication and ongoing engagement with companies would be critical to the project's success. A consistent set of concerns emerged from companies including:

- **Ensuring different levels within the company** (e.g., VP, site manager, process engineer) understood and supported the purpose, goals and objectives of the project and that this support was communicated to those who would actually be engaging with the project team;
- The limited time of site staff to engage with the project team given all of their other duties, and because many facilities were understaffed;
- Concerns around the confidentiality of the information requested by the project team and whether government and competitors would be able to see it.

Communication with companies was ongoing throughout the project and included:

- **Developing a succinct project information package** that included a 2-page communication overview.
- **Holding a project kick-off meeting** for confirmed and potential industry participants to address any concerns around confidentiality and how the project team intended to minimize the time burden on their staff.
- **Individually engaging company representatives** (process managers and site engineers) who had been designated by site managers to assist the project team.
- **Signing non-disclosure agreements** with company participants to prevent any of the site-level information provided from being released publically or made available to provincial or federal government departments. Only regionally aggregated information can be released by the project team to protect the identities of individual companies.
- **Hosting onsite meetings with select companies** where the project team had identified potential waste heat opportunities or conducting additional follow-up phone-calls with sites, which had a large amount of potentially viable waste energy. The purpose of these meetings was to better understand each of the identified streams (e.g., are they physically accessible, how temporally variable are they, better understand other relevant aspects of the original process, risks, etc.) and get individual feedback from the company around the policy, regulatory, or operational barriers which could inhibit the use of the streams.
- **Hosting a follow-up meeting** with company participants to present the emerging regional waste energy picture to companies, showing how the project team would be aggregating their company data, and outlining any remaining tasks, which needed to be accomplished to complete the study.

- **Ensuring transparency** around the data gathering and analysis process and utilizing expert-panel members to help the project team identify potential barriers and uses for the waste energy streams.
- **Forwarding a draft project report to all company participants** and completing follow-up phone calls and meetings with individual companies.

## 4.3 REVIEW OF OTHER INDUSTRIAL PARKS

The Community Integrated Energy Mapping Feasibility Study represents the first regional industrial waste energy study to be completed in Canada. Energy mapping however, has been conducted in other parts of the world. To better understand what was learned from these studies and how this could advance energy mapping activities in Alberta, various industrial parks both within Canada and globally, were examined and some were interviewed<sup>18</sup> (see the Appendix for more details on the industrial parks).

The selected parks which were reviewed had similarities to the AIH and SIA, and included:

### **Goteborg Energi District Energy System, Sweden**

- This district energy system's roots go back to the 1950s when the first combined heat and power plant was installed. In the 1970s, the city's waste incinerator started delivering heat into the district heating system, and by the end of the 1970s, eight large heating islands were linked together and fed into the district heating system. In the 1990s the system started using heat to deliver cooling during the summer months, and in 2003 a major natural gas fired combined heat and power plant was converted to wood pellets.
- Some of the key drivers of the ongoing transformation of this industrial area have included:
  - Support from the local municipalities, including densified development in close proximity to the waste heat sources;
  - Energy taxes and carbon prices created the necessary economic incentives to find uses for waste energy streams and also create greater energy integration;
  - Government financing at various stages in the development of the district energy system helped overcome capital constraints for building the required infrastructure;
  - Experience and knowledge around operating district utility systems was available since Goteborg built and operated a natural gas distribution system in the 18<sup>th</sup> century.

### **Proposed Waste Heat Recovery/District Heating Project at the Port of Antwerp, Belgium**

- In 2010, the Port of Antwerp completed a heat mapping study of ~150 km<sup>2</sup> of industrial lands and identified an abundant supply of low temperature energy (~1000 MW of waste heat with temperatures >80°C). In 2012 a feasibility study was conducted to examine a number of potential uses for this energy and found that the business case for using waste heat in greenhouses, for generating electricity with Organic Rankine Cycle, and for demineralizing water were all not

---

<sup>18</sup> Harris S, 2008. Mechanisms to Enable Regional Resource Synergies: Facilitating Structures and operational Arrangements. Centre of Excellence in Cleaner Production, Bulletin No. 3. Curtin University of Technology, Perth.

viable. A follow-up study in 2013 looked at ways to build a local market for waste heat and concluded that the best way to create a market for the industrial waste heat is to use or create locally available heat sources to stimulate the development of local market demand. The existence of such market demand can then be used to justify the capital costs associated with capturing and transporting the industrial waste heat to these markets. The region is continuing to work towards finding viable ways to implement these ideas.

### **Industrial Cogeneration Projects in Sarnia-Lambton, Ontario**

- Back in 1995, three large industrial facilities created an Energy Joint Venture to enable the sharing of steam and electricity between the facilities. Steam and electricity were generated on two of the sites, and excess electricity was sold to Ontario Hydro. In 1997, the concept of a regional cogeneration facility in Sarnia was initiated with plans for 523 MW of electricity generation and 1.6 million pounds of steam per hour to be sold to seven industrial clients. The Energy Joint Venture's assets were purchased by TransAlta in 2002, and commercial operation of the Regional Cogeneration Plant began in 2003. In 2006, DOW (one of the producers and also consumers of steam and electricity in the original joint venture) announced that it was closing its Sarnia operations and in 2009 the DOW site was sold to TransAlta Corporation. Bluewater Energy Park opened on the former DOW property in 2010 and provides "behind-the-fence" electricity rates to any tenant who locates in this park, and a number of clients have since done so. The vision is to create a unique Sarnia-Lambton Energy Advantage by using regional cogeneration to attract investment and help existing industry already become more competitive through lower power rates.
- Some of the drivers operating in Sarnia include:
  - Electricity prices increased dramatically in the early 1990s, necessitating the search for ways to reduce prices. Local economic development organizations acted as a catalyst to overcome barriers, in particular around how to coordinate independent companies.
  - Changes in provincial electricity policy were needed and were obtained to enable the sale of electricity between industry members regionally, and to allow TransAlta's behind-the-fence pricing in the Bluewater Energy Park.
  - Research was done to evaluate the alternative types of industrial partnerships to find a workable model.

### **Shell Scotford Manufacturing Centre in Alberta's Industrial Heartland**

- This site consists of four plants (upgrader, refinery, chemicals, and also COGEN with steam generation) which exchange materials and energy with each other and is a good example of the kinds of synergies which are possible, not only within a site, but also with neighbouring sites. A lot of the steam and power generation needed is done with COGEN. Shell owns and operates a steam turbine on site, while ATCO operates a cogeneration plant, which produces steam from the exhaust gas of the gas turbine. Air Liquide operates a COGEN plant, which sends steam and electricity to the chemicals plant, along with oxygen and nitrogen. Air Liquide also recovers and purifies a portion of CO<sub>2</sub> from Shell's glycol operations for use in enhanced oil recovery and non-industrial uses. Aux Sable processes refinery off-gases (recovering natural gas liquids, ethane and hydrogen from these streams) and sends the hydrogen back to the Shell Scotford hydrogen header system.

- Shell Scotford continues to develop synergies with its neighbours. Air Products is currently building a new plant near Scotford, which will produce hydrogen and also supply Scotford with steam. In 2015, the Quest Carbon Capture and Storage (CCS) project will capture more than one megatonne of CO<sub>2</sub> per year, or 35% of the Shell Scotford Upgrader's yearly GHG emissions. The CO<sub>2</sub> will be purified and compressed at the Scotford facility and transported by pipeline to underground injection wells.
- The drivers behind such integration at Shell's site have included:
  - Lots of company-wide and on-site evidence for the efficiency benefits of greater energy integration, along with reduced production risks to plant operations through enhanced plant reliability.
  - As one of Alberta's newer facilities, efficiencies could more easily be designed into the plants when they were constructed.
  - Shell uses a lower return on investment hurdle rate for energy efficiency projects relative to production projects. This enables energy efficiency projects to be undertaken - although cost/benefit is still a major driver for any project.

The review of industrial parks around the world demonstrates that three critical factors must be satisfied for stakeholders to even begin the first phase of this long-term transformation to greater industrial integration:

1. **A Convincing Business Case Must Exist** – meaning that ways to reduce costs or generate new revenue have been identified and can actually be undertaken by business;
2. **The Social License to Achieve Efficiencies Exists** – meaning that policy or regulatory barriers to achieving efficiencies can be overcome, and communities potentially affected by the initiative endorse the initiatives;
3. **Use of Proven Technology** – in that the processes and equipment needed to enable resource synergies exists, have been proven, and have low implementation risks.

Program design for energy mapping in the AIH and SIA considered what was learned from the review of other industrial parks to satisfy the three factors above. The long-term goal is the creation of the conditions needed to assist these industrial areas on their journeys in becoming eco-industrial parks.

## 4.4 DATA CAPTURE AND ANALYSIS

To secure and maintain industry support for this project, it was critical to minimize the resources companies would need to devote to this project as many were short-staffed and thus had limited ability to engage in activities outside their core operations.

With respect to site-level energy inputs, companies were generally sensitive to revealing the quantities of their energy inputs - even with a non-disclosure agreement in place. Since energy demands could be roughly estimated based on published life-cycle assessments or other types of process analyses, and given that the primary focus of this study was to assess how much waste heat existed across these industrial

areas, a decision was made to devote our efforts on getting companies to reveal waste energy information. This seemed the best strategy for building long-term company support for this and potential future project phases.

For site-level energy outputs, the project focused on obtaining the following information from companies:

- **A description of the major energy types used** (typically natural gas, steam, refinery gas, electricity, petroleum coke, diluted bitumen (dilbit, field grade butane, and hydrogen). In some cases, this also included steam from a neighbouring site);
- **The quantity used** (e.g., MJ over a day);
- **Description of how the energy is used** (e.g., process heating to 250 °C);
- **Description of the variability in demand** (e.g., over a day or seasonally);
- **Other relevant process details and comments** (e.g., pollutant level of the exhaust stack, other risks or issues in trying to capture the energy, etc.).

To understand how the results of this study can (and cannot) be interpreted, it is important to be clear on the approach used to obtain data and information from participating companies:

1. **It was assumed that sites are internally optimized with no economically viable opportunities to use waste energy on site.** The purpose of this study was to examine regional waste heat opportunities – not optimize industrial processes which is something best done by highly specialized consulting firms. If there are economically viable ways to use waste heat on a site, competitive pressures should imply that companies will work to realize these cost savings. The focus of this study is on identifying and quantifying what waste energy sources still exist on sites after they have done such site-level analyses.
2. **Site personnel engaged on this project were encouraged to use the “80-20 Rule” and only describe “major” energy flows across their sites.** Given limitations on staff time, the advice given was to focus on reporting significant waste energy streams on site, rather than trying to quantify a myriad of small energy streams, which could never be economically captured. Under Alberta’s Specified Greenhouse Gas Emitters Regulations<sup>19</sup>, companies are required to have their reported CO<sub>2</sub>e emissions verified by an external energy auditor before they are submitted to the Government. Thus, our assumption was that process managers would be very knowledgeable regarding the energy efficiencies of the various processes they manage. Our experiences on this study confirmed this assumption. Simple data templates were used to help ensure data was gathered in a consistent fashion.
3. **All data was self-reported by companies.** Safety and security concerns mean that getting access to sites to do energy audits would have been very challenging. In addition, companies

---

<sup>19</sup> <http://esrd.alberta.ca/focus/alberta-and-climate-change/regulating-greenhouse-gas-emissions/greenhouse-gas-reporting-program.aspx>

have already done energy audits and have a good enough understanding of waste energy flows for this feasibility study. Having companies self-report the information also afforded the opportunity to have further conversations with staff – thereby enabling the project team to further explain the project to them, and also gain other valuable insights. For example, in many cases we heard about waste energy streams which were going to be modified due to plant upgrades or maintenance in the next few years, or about compressed streams which were being let down in pressure, or some of the previous work they had done in trying to use waste energy sources on site. Such insights would have been missed if energy auditors simply audited the site without engaging site personnel.

Three primary types of waste heat were identified across the two industrial areas: exhaust stacks, coolers and compressors, and also pressure letdowns of high-pressure streams. Each significant source of waste energy (e.g., a single exhaust stack, a cooling tower) is referred to as a waste energy stream. The information collected on each of these streams, along with how this information was converted into potentially recoverable energy, is summarized below. Greater detail is given in the Appendix.

#### 4.4.1 EXHAUST STACKS

Exhaust stacks represent the vast majority of waste energy streams in the two industrial areas. Most of these stacks originated from some kind of heater or boiler, although a few stacks originated from gas turbines or petcoke pyrolysis. For such waste heat streams, the following information was requested:

- **Description of the exhaust source;**
- **Fuel type** (e.g., natural gas, refinery gas);
- **Rate of exhaust gas flow** (m<sup>3</sup>/s or kg/s);
- **Temperature of the exhaust gas stream** (°C);
- **Qualitative description of contaminants in the stream** (e.g., high NO<sub>x</sub> or SO<sub>x</sub>) and temporal variability (or lack of).

To meaningfully summarize the exhaust stack information, each exhaust stream was classified based on a number of criteria:

- **Pollutant Level** - Low – meaning minimal risks associated with lowering the stack temperature; High – meaning unacceptable risks such as stack corrosion based on available technologies or impossible under current regulations. High pollutant stacks also included emergency flares, which are intermittent.
- **Temperature Category** – exhaust stacks were classified into one of three different temperature categories:
  - Low (120-230 °C);
  - Mid (230-650 °C);
  - High (650-1100 °C).

- **Size of the Stream (MW).** To meaningfully identify streams with large amounts of waste energy, the amount of sensible heat<sup>20</sup> energy released by cooling each stream to 120 °C was computed. Thus, it was assumed that the lowest stack temperature exhaust streams could be reduced to without condensation is 120 °C. It should be noted that calculating how much energy could be released from cooling to 120 °C does not mean that the stream can, in reality, actually be cooled to this temperature without harmful consequences to equipment. Instead, cooling streams to this common temperature makes it possible to identify which exhaust streams contain the largest amount of energy. In addition, the sensible and latent heat of cooling each stream from 120 to 40 °C was also computed to capture the amount of energy if water vapour in the stream were condensed. This later calculation is for theoretical purposes and does not imply that it should or could actually be done.

To compute both the sensible and latent heat from cooling the exhaust streams, Aspen Plus® was used to calculate the heat content of the stream assuming natural gas as the fuel source. Natural gas was the fuel source in the vast majority of exhaust streams reported, although some utilized a mixture of natural gas and refinery fuel gas. A number of specific cases had to be considered in these computations:

- **Heaters or Gas Fired Boilers** – in this case a natural gas feed was assumed, 10% excess air, and complete combustion of methane to CO<sub>2</sub> and H<sub>2</sub>O. Based on the Aspen Plus® model built, a simple equation was constructed to estimate the amount of sensible heat from cooling to 120 °C, and the sensible and latent heat from cooling from 120 to 40 °C (see Appendix for the equation and assumptions).
- **Gas Turbine** – in this case a natural gas feed was assumed, 200% excess air, complete combustion of the methane to CO<sub>2</sub> and H<sub>2</sub>O. The equation for estimating the amount of sensible heat from cooling to 120 °C, and sensible and latent heat from cooling from 120 to 40 °C are given in the Appendix.
- **Petcoke Pyrolysis** – in this case it was assumed that carbon is the fuel, 20% excess air and complete combustion of the carbon to CO<sub>2</sub>, and additional water was added to reach a stack moisture content of 12%. For this specific case, it was assumed that the lowest practical stack temperature without condensing was 175 °C (not 120 °C) to prevent condensation of corrosive compounds. Note that such streams were still aggregated in with the other streams cooled to 120 °C. This exception was made for pragmatic reasons based on the nature and magnitude of these particular exhaust streams and given that doing so would not impact the final interpretation of results or conclusions made. The detailed assumptions and equations are given in the Appendix.

#### 4.4.2 COOLERS AND COMPRESSORS

Waste energy from coolers and compressors was found to exist on a number of sites. Such energy is typically released from a liquid or a compressed stream. For example, some compressors use oil cooling to remove energy when gases are compressed, or alternatively sometimes energy needs to be removed before a material can proceed to a subsequent process. The types of information requested included:

---

<sup>20</sup> Sensible heat is thermal energy whose transfer to or from a substance results in a change of temperature; Latent heat is heat given off or absorbed in a process (as fusion or vaporization) not involving a change of temperature

- **Description of the source of the heated stream** (e.g., cooling water or product coming from a compressor).
- **Input temperature of the stream before the cooler** (°C).
- **Output temperature of the stream after the cooler** (°C).
- **Flow rate of the material through the cooler** (kg/s).
- **Specific heat capacity of the liquid** (J/kg K) or total energy rejected (MW).
- **Qualitative comments about the variability or other potential issues with this stream** (e.g., intermittency, ability to access).

These streams were divided into three temperature categories, which are lower than those used for exhaust stacks:

1. Low (20-80 °C)
2. Mid (80-140 °C)
3. High (140-230 °C)

Based on the temperature drop across the cooler and the other information provided, the amount of energy being rejected by these sources could be computed.

## 5 RESULTS

---

A significant amount of waste heat was discovered in the Strathcona and Heartland industrial areas. Geographically, the waste heat was clustered in three heat islands (Figure 2) across these two industrial areas. The results contain many subtleties, which will be explained in greater detail below, but in aggregate across the 17 participating sites with energy streams which could likely be recovered (i.e., just low pollutant exhaust streams) the study identified:

- 300 MW of sensible waste energy, of which:
  - 64 MW came from exhaust stacks with temperatures between 230 and 1100 °C;
  - 85 MW came from exhaust stacks with temperatures between 120 to 230 °C;
  - 151 MW came from coolers and compressors with temperatures between 80 and 230 °C.

It should be stressed that these results are only for the participating sites (shown with the red squares in Figure 2). Other companies known to have significant amounts of waste heat did not participate in the study. Further, not all participating companies reported on all of their major waste heat streams (e.g., a few only reported on exhaust stacks, but not cooling towers). Finally, lower temperature cooling streams between 20 and 80 °C have been excluded from this figure due to the inherent challenges of repurposing such low temperature heat, but these results are included in the more detailed discussion below. Thus, the study's results above are conservative relative to the actual waste energy available in these industrial areas.

Given that not all of the identified waste energy identified could ever be captured, to make the results more realistic it was assumed that 33% of this total waste energy could be captured and repurposed. The resulting 99 MW of waste energy could theoretically be used to:

- Heat 15,200 average homes<sup>21</sup>;
- Generate 5 MW of power - enough to power 5,100 homes<sup>22</sup>;
- Reduce CO<sub>2</sub>e emissions in the region by ~151,000 tonnes<sup>23</sup>.

Such comparisons are included to make the findings more meaningful and understandable to the reader – not to suggest the best possible use for these waste energy streams.

As there are practical limits to how far waste heat can be transported, Figure 2 shows red circles around each heat island, which are 10 km in diameter to give an indication of the distance to surrounding communities. For each heat island, assuming that 33% of the waste energy available in each heat island could be repurposed, it would mean that:

---

21 Assuming that heating a house requires 160 GJ of natural gas.

22 That 20-30% of the waste energy (depending on temperature) could be converted to power, and that a house requires 7,800 kWh of power a year.

23 Based on NRCAN emission reduction factors (<http://www.nrcan.gc.ca/energy/efficiency/industry/technical-info/benchmarking/canadian-steel-industry/5193>).

- **Strathcona** - 65 MW of waste energy is available, which theoretically could be used to heat 10,200 houses, generate 3 MW of electricity and produce enough power for 3,300 houses. In total this could result in a 101,000 tonne reduction in CO<sub>2</sub>e per year.
- **Heartland near Ft Saskatchewan** - 16 MW of waste energy is available which could theoretically heat 1,500 houses, generate 2 MW of electricity (which could in turn power 1,800 homes), and would reduce GHG emissions by ~18,000 tonnes per year.
- **Heartland near Scotford** – the total waste energy of 18 MW is sufficient to heat 3,500 homes which could reduce GHGs by ~32,000 tonnes.

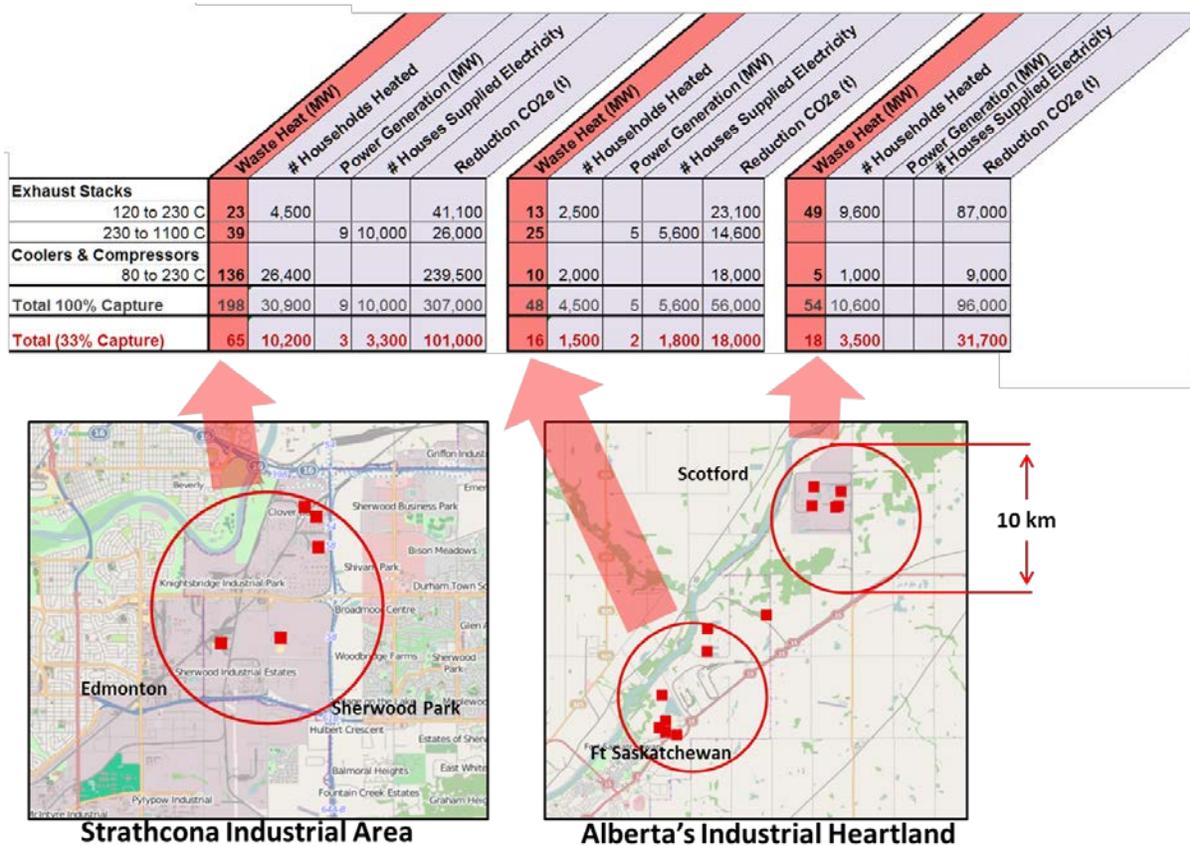


Figure 2: Aggregate summary of the amount of potentially recoverable waste heat from exhaust stacks, coolers and compressors across the heat islands identified in the two industrial areas. Energy sources which had high levels of pollutants or other associated risks are NOT included in this summary. The diameter of each red circle

For sites in these industrial areas which report under Alberta’s Specified Greenhouse Gas Emitters Regulations, the total GHG emissions was used to estimate the percent decrease in GHG emissions which would be achieved if the types of waste energies reported in Figure 2 on each site could be reused. Assuming 33% of such streams could be reused, the resulting percentage reductions in GHG emissions would range from approximately 0.5 to 10%.

The above results for low-pollutant exhaust streams, along with coolers and compressors are discussed in greater detail below. These results only deal with the sensible heat from cooling exhaust streams to 120 °C. The sensible + latent heat from cooling these low-pollutant streams from 120 to 40 °C is presented in the Appendix. These results, while interesting theoretically, have limited practical utility. Finally, the amount of sensible energy in high-pollutant exhaust streams, or exhaust streams with other significant operational risk factors (and thus not discussed in this section) are also presented in the Appendix. The purpose of including results for high-pollutant streams is to give an idea of the magnitude of the amount of energy in such streams which could possibly be repurposed if significant technological, material, regulatory, or cost barriers could be overcome.

## 5.1 LOW POLLUTANT EXHAUST STACKS – SENSIBLE WASTE HEAT FROM COOLING TO 120 °C

The amount of thermal energy released by low pollutant exhaust stacks by temperature category and the amount of energy in each stream is shown in Figure 3 by each major industrial area. To avoid revealing individual company data in this more detailed discussion, the waste heat islands in the Heartland have been combined.

For low temperature exhaust streams between 120 to 230 °C which are larger than 1 MW size, Strathcona has a total of 19 MW of such waste energy streams, with 8 MW coming from streams larger than 3 MW in size. In the Heartland, there is a total of 58 MW of streams in this temperature range, which are greater than 1 MW in size, and 53 MW comes from individual streams which are larger than 3 MW.

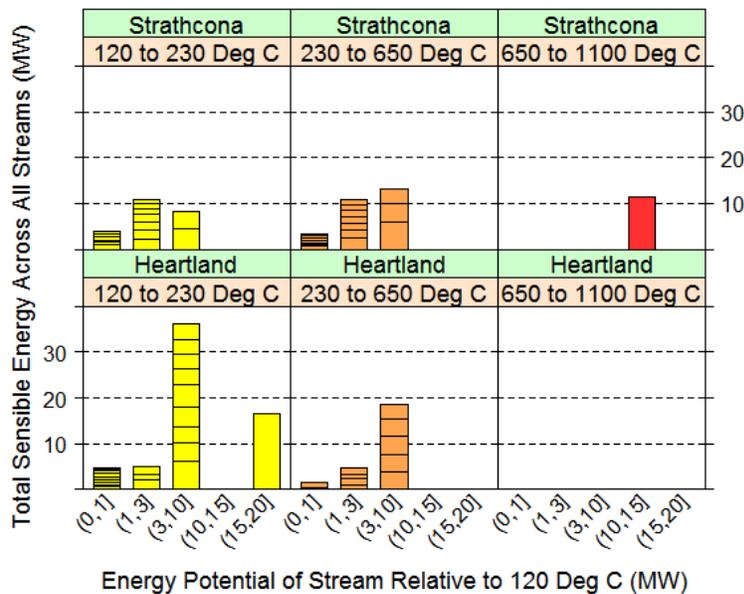


Figure 3: Low pollutant exhaust streams grouped by size (e.g., 0-1, 1-3, 3-10 MW) and temperature across the two industrial areas. The total rejected sensible energy (MW) is computed relative to cooling each stream to 120 °C. The horizontal lines within each bar represent individual

Figure 4 shows the size of the individual waste energy streams for exhaust stack plotted against the temperature of the stream. Given that the range of temperatures used to define low, medium, and high temperature categories is quite large, these plots show whether the streams are all clustered near the 230 °C boundary, the boundary at 630 °C, or somewhere between these two cut-offs. For the exhaust stacks shown in Figure 4, many of these streams are above 350 °C and larger than 1 MW in size.

Strathcona does have a single high temperature exhaust stream (11.5 MW with a temperature greater than 1000 °C), and both industrial areas have a fair amount of energy in exhaust streams which are between 230-650 °C. For stacks releasing more than 1 MW of energy in Strathcona, 24 MW of energy is being released which is in this mid-temperature range, and 13 MW of this energy comes from streams, which are between 3-10 MW in size. For stacks releasing more than 1 MW of energy in the Heartland, 24 MW of the rejected energy is between 230-650 °C, and 19 MW is coming from stacks which are 3-10 MW in size. Thus, both industrial areas are rejecting a large amount of energy in exhaust streams between 230-650 °C where the amount of energy in each individual stream is greater than 3 MW in size.

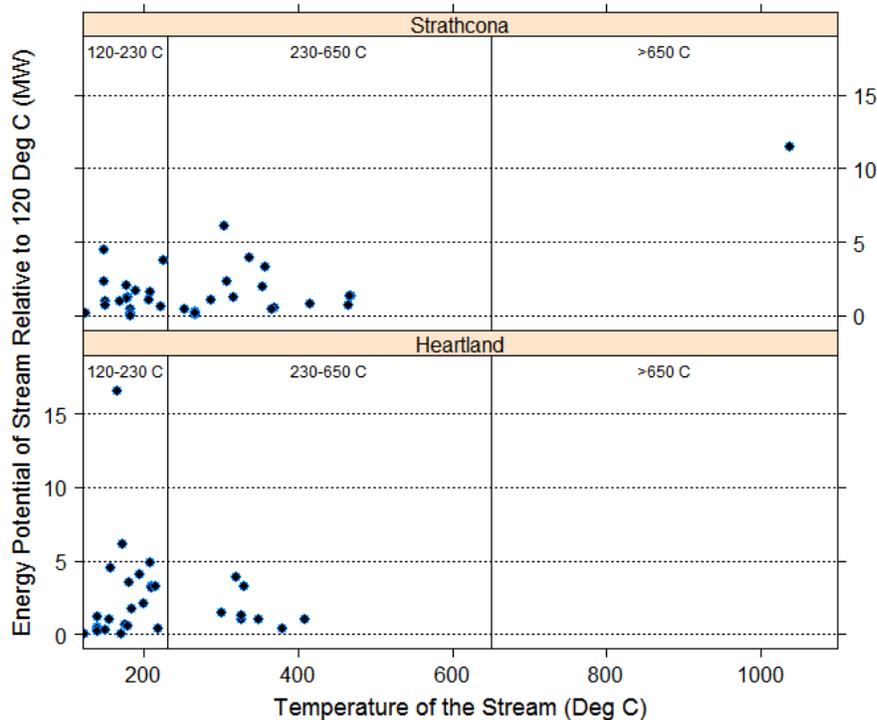


Figure 4: Estimated rejected energy of low pollutant exhaust streams relative to cooling the stream to 120 °C (i.e., sensible energy) relative to the original temperature of the stream across the two industrial areas.

To determine whether the waste energy sources are coming from a small handful of sites or whether many individual sites are releasing smaller amounts of waste energy, the total amount of waste energy coming from each site was plotted (see Figure 5). Note that an anonymous site ID has been used to maintain

confidentiality of companies. It is clear from Figure 5 that both mid and high quality waste energy streams are clustered across just a few industrial sites, rather than being evenly distributed across sites. This is important as it could make capture of the waste energies easier since the required infrastructure could potentially be targeted to just those sites with the most waste energy.

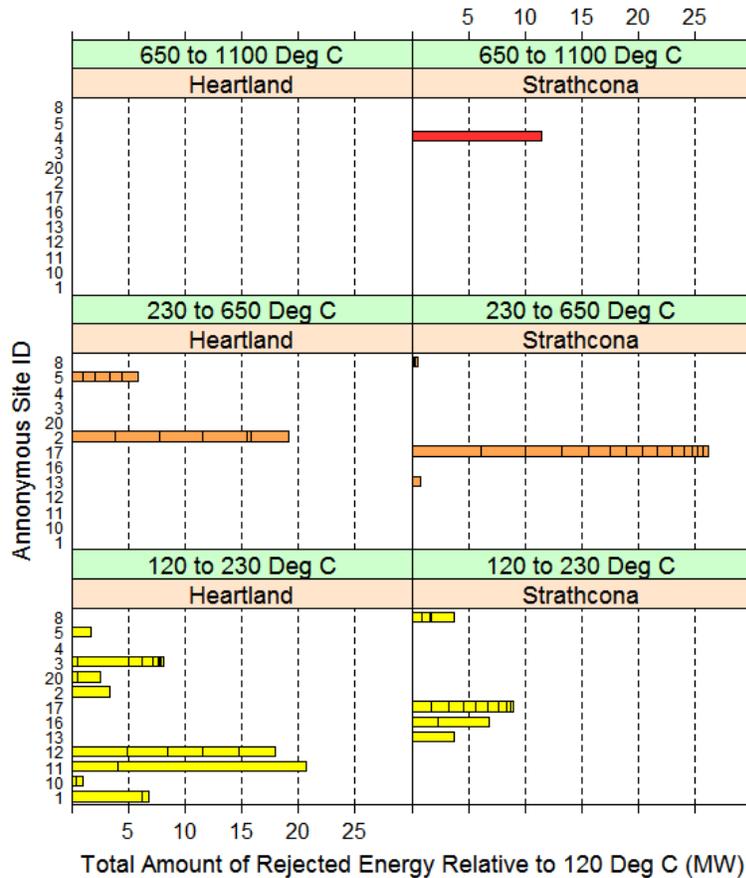


Figure 5: Low pollutant exhaust streams grouped by their originating site across the two industrial areas and also the temperature category of the stream. An anonymous site ID has been used to maintain site anonymity. The total rejected sensible energy (MW) is computed relative to cooling each stream to 120 °C. The lines within each horizontal bar indicate the sizes of the waste energy streams.

## 5.2 COOLERS AND COMPRESSORS

A major source of waste energy in both industrial areas came from the cooling of liquid streams which originate from cooling intermediary products through fin-fan coolers, cooling towers, etc. Compressors used to increase the pressure of gases may also have associated coolers (e.g., wet screw compressors) and so are included in this section.

The results in Figure 6 are presented similarly to those in Figure 3. Across the two industrial areas, cooling streams are grouped by the amount of energy being rejected, and the temperature category of the

stream. For cooling streams between 140 and 230 °C, a total of 33 MW of waste energy is being released in the Strathcona industrial area. Two of these streams are greater than 10 MW in size. The Heartland region had a total of 13 MW of rejected energy from coolers within this temperature range.

For streams with temperatures between 80 and 140 °C, Strathcona had a total of 102 MW (with two of the streams approximately 35 MW in size). Within the Heartland, only 2 MW of such rejected energy was reported within this temperature range.

As would be expected, both the Strathcona and Heartland Industrial areas release a large amount of low temperature (< 80 °C) heat through their coolers: 112 MW in Strathcona, and 453 MW in the Heartland.

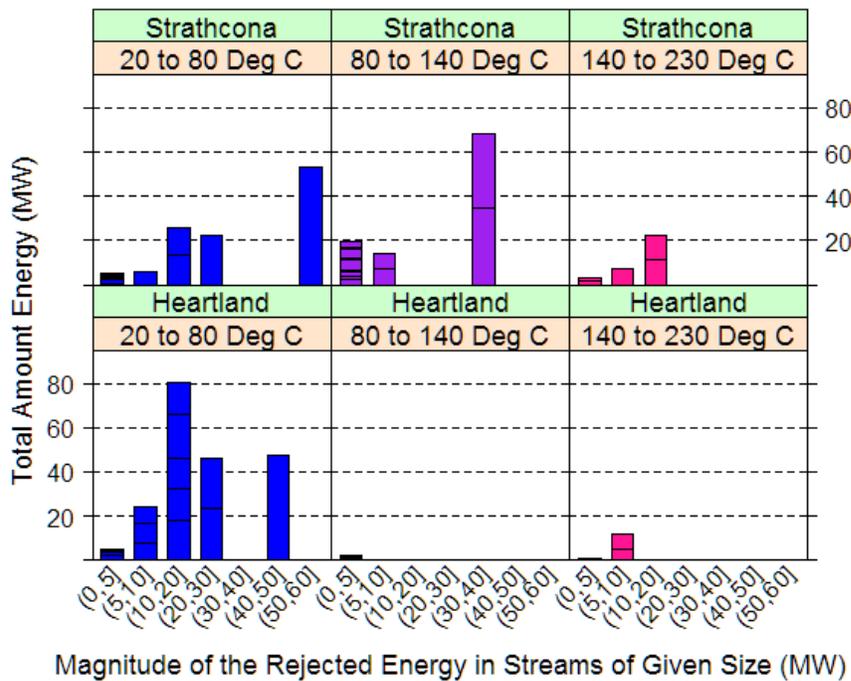


Figure 6: Total energy rejected by cooling & compressor streams grouped by size (0-5, 5-10, ..., 50-60 MW), the industrial area, and the temperature of the stream before it is cooled. Note that lower temperature ranges are used relative to the temperature categories used with exhaust stacks in Figure 7.

A scatter plot of the temperature of each stream against the size of each cooling stream is given in Figure 7, showing the size of these low temperature streams, and also that a few higher temperature cooling streams are of significant size.

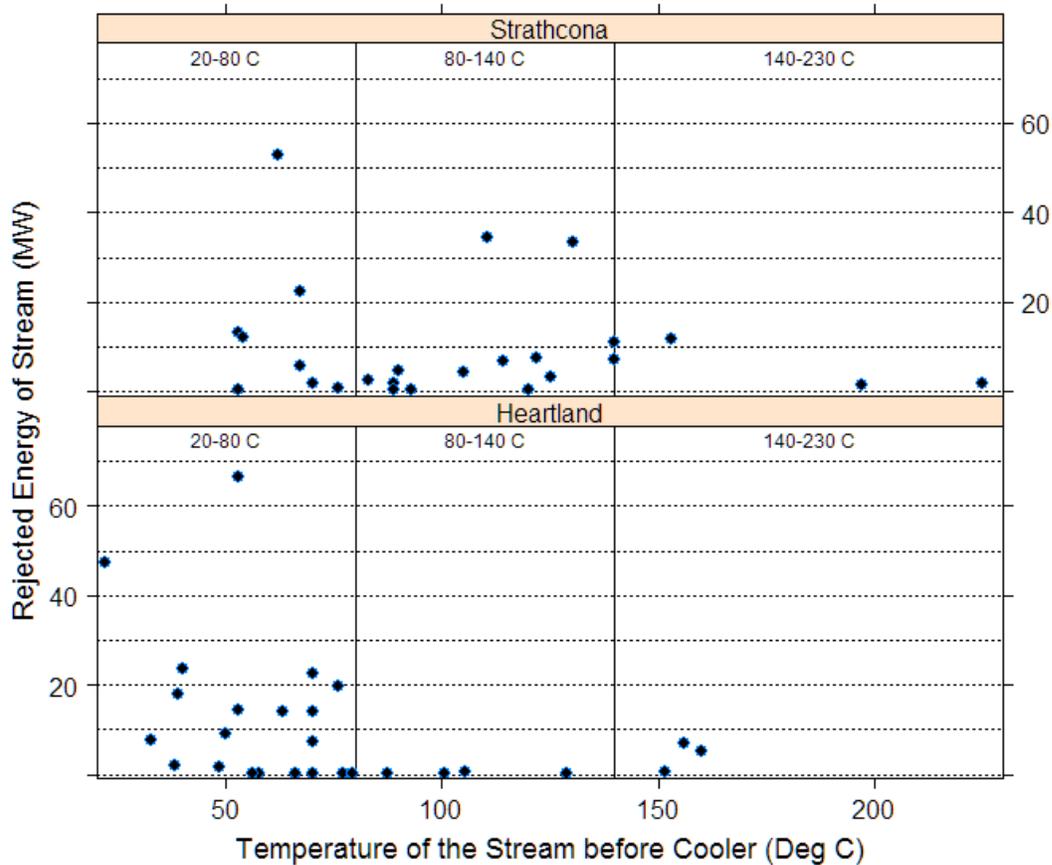


Figure 7: Amount of rejected energy by streams associated with coolers and compressors relative to the temperature of the stream before it passes through the cooler (e.g., fin fan cooler, cooling tower).

To assess whether the energy being rejected from coolers is clustered on just a few sites or more evenly distributed across sites, the total amount of waste energy by temperature category for each site (indicated with an anonymous site ID) is shown in Figure 8. Similar to exhaust stacks in Figure 5, waste energy streams from coolers and compressors are clustered by site with most of the higher temperature streams greater than 5 MW in size originating on just a few industrial sites.

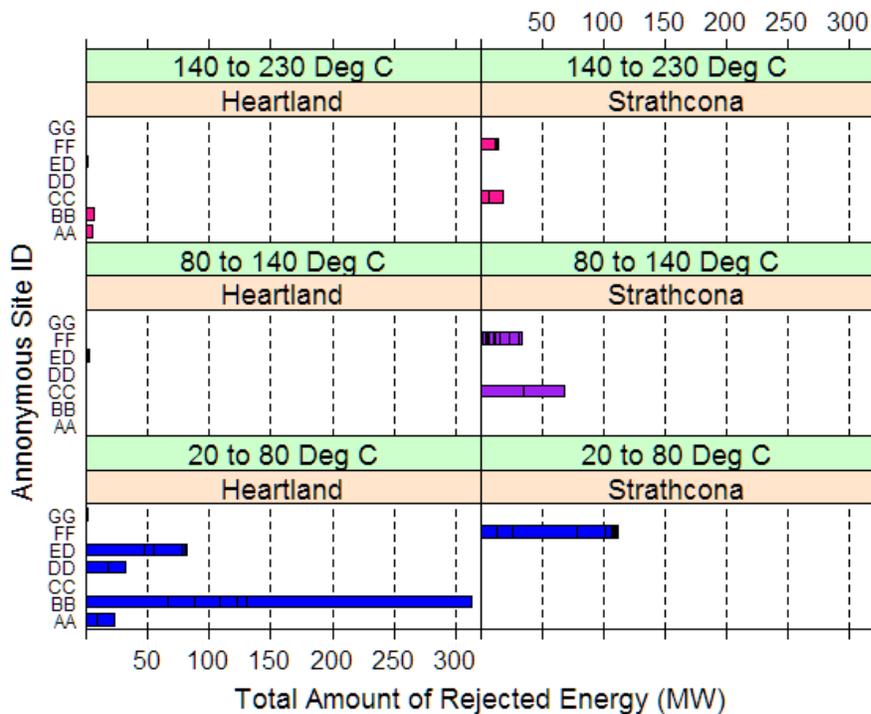


Figure 8: Total energy rejected by cooling & compressor streams (according to anonymous site ID), the industrial area, and the temperature category of the stream before it is cooled. Note that lower temperature ranges are used compared to those used for exhaust stacks.

### 5.3 LETDOWN OF PRESSURIZED STREAMS

One important piece of feedback received from companies is that each region is served by a variety of natural gas pressures. One or more high-pressure natural gas pipelines serve each region, and the pressures are letdown to supply facilities. Factors such as the amount and specific pressure needed by site processes determine the pressure at which natural gas is delivered to a site. Only a few sites require high-pressure natural gas. The pressure letdown between the high-pressure natural gas pipeline and end uses could be another source of waste energy, which could be captured using a pressure-reducing turbine.

It was difficult acquiring good information on the pressure within the high-pressure natural gas pipelines, which supply these industrial areas, the pressures that are needed on sites, and thus what the size of the waste energy opportunity may be. Some sources of information suggest the pressures in the high-pressure natural gas system are between 800 to 1000 PSIG (5500 to 6900 kPa), while others suggest it is lower. On industrial sites, applications such as burners typically only require natural gas pressures in the range of 10 PSIG (70 kPa). One site estimated that such pressure letdowns associated with its natural gas consumption could generate between 1-2 MW of electricity. Given the way in which natural gas is supplied to sites, in some cases the pressure letdown opportunity may lie with the natural gas supplier, or alternatively on an actual site.

Another pressure letdown opportunity exists when NGL products are removed from underground storage. The pressure differential between NGL liquids in storage and the pressure in the pipeline used to transport the product to market differs by ~10 MPa. This pressure differential will change depending on how full or empty the storage cavern is. Turbo expander technology could potentially be used in this context as well. However, any supply of electricity from such sources would be highly intermittent, given that as market conditions for the NGL products fluctuate over time the facility will switch between pumping the products into storage, or taking the products out of storage and shipping them down the pipeline.

## 5.4 SUMMARY OF MESSAGES HEARD FROM COMPANIES

In addition to the quantitative information around waste heat sources obtained from companies, phone conversations and site visits also revealed useful qualitative information about the barriers and concerns companies had around a variety of issues relevant to trying to improve site energy efficiencies and the barriers to greater regional energy integration. These are briefly discussed below.

### Challenges of Added Complexity

- The additional complexity of trying to capture and use waste heat sources is problematic for many companies because operating and maintaining such equipment is outside their core operations. And although many sites said that they had evaluated heat capture technologies at some point in the past, the economics for using such technologies was generally not compelling when most companies apply ROI hurdle rates of 30-40% for any kind of site investment. The challenge is that even with hurdle rates of 10-12%, most energy efficiency investments do not make the cut. The added complexity coupled with low ROI means that most energy efficiency investments are unlikely to ever occur. A couple of examples can be given.
  - For some sites, generating steam from waste heat sources would have required the installation of a water treatment plant or locating another site willing to sell excess water treatment capacity. However, the risks of ensuring an adequate supply of water to the receiving site mean that the site supplying the water would have to increase the price to offset its risks. The increasing price of water would only make the economics of the project even more challenging.
  - Presently, hydrogen is distributed to companies in the Strathcona and Heartland areas via a high-pressure pipeline. However, some of the major users of hydrogen do not require the hydrogen to be at such a high pressure and are also located near to the hydrogen production plant. This creates the possibility of developing a separate low-pressure hydrogen line just to serve such sites. The benefits were roughly estimated by a company to be ~\$1-2 million per year. However, the main challenges to realizing this are infrastructure costs (which would be substantial and would have a long pay-back time) and also determining how to share the resulting GHG reductions between the producers and consumers of the hydrogen.
- Many companies expressed concerns about deploying heat capture technologies on their sites because of the unknown risks they might be introducing to their processes, which could jeopardize their operations. Many site personnel said that before they would deploy any kind of heat capture technology, they would first want to learn how it was deployed and to see how it is currently operating at similar plants to understand what issues were encountered and how these issues were mitigated.

## Planning and Operational Barriers

- Sites in both industrial areas are typically situated large distances from each other making the transport of waste energy between sites challenging in terms of infrastructure costs. The large distances also make it more challenging to find the right “match” between available energy sources and nearby energy demands. For example, in one case the amount of steam which could be supplied by a site was only sufficient to displace half of a boiler at the neighbouring site, meaning the neighbouring site would still have to keep operating its boiler, but only at 50% capacity and thus much lower efficiency. The greater the number of industrial sites which can be placed within the same geographic area, the easier it becomes to find optimal bilateral or trilateral synergies.
- Accessing waste heat streams on industrial sites can be difficult if other infrastructure (e.g., pipes, other exhaust stacks, etc.) surrounds the waste energy sources to be captured, or if the waste heat sources are situated high above the ground.
- To minimize costs, it is critical to identify and exploit potential synergies while new plants are being planned or long before they are scheduled to undergo major retrofits. For example, one company in China, with similar operations to those in the Heartland, had no problem finding a market for the waste heat it would generate and given that all the neighbouring plants were still at the design stage, it was able to incorporate the exchange of waste heat from its plant to neighbouring plants. The boilers in a number of large industrial sites in the Strathcona Industrial area are nearing the end of their life and will need to be replaced. This could open up a unique opportunity to find similar kinds of synergies. In the Heartland, a large amount of new development is also occurring around the Shell Scotford Manufacturing Facility; however, given that this development is already underway it is unclear how easily industrial synergies could be realized at this stage.
- A number of companies said they would be willing to consider simply tapping into a district steam system provided such system was cost competitive and had greater reliability than the steam systems which they currently operate on site. An advantage to individual companies of relying on a larger district steam is that the greater reliability of the steam system would reduce the operational risks of tripping a costly plant shutdown. The current expansion in the regional hydrogen supply network illustrates these benefits.
  - A new hydrogen plant is under construction near Scotford, which will be connected to the region’s hydrogen pipeline. With two geographically separated facilities feeding the hydrogen pipeline, the risks of a disruption in the hydrogen supply will be greatly reduced. Presently, companies operate their own hydrogen production to supplement the hydrogen supply they receive from the hydrogen pipeline because any interruption in supply forces them to shut down their plant - which is costly. Once the new hydrogen plant is operational, a number of companies said that they would be looking at shutting down their on-site hydrogen production – provided the risks of a supply disruption are sufficiently low.

## Government Policy and Regulations

- The lack of clarity around how government will set baselines for measuring future GHG reductions is acting as a barrier to companies being proactive about improving their energy efficiency. This is because it is unclear whether plants which have already achieved significant GHG reductions or are already highly efficient relative to other similar plants will be treated the same as less efficient plants in terms of expected future GHG reductions. If all plants are expected to achieve similar GHG reductions, this would penalize plants which made efficiency improvements before the baseline was set.
- One of the reasons some companies were not eager to try generating electricity from waste heat sources is the complexity associated with selling the power to the Alberta Electrical Systems Operator when the supplies are small and/or temporally variable. Further, in Alberta's deregulated electricity market it is hard to get certainty around future power prices for selling power to the grid. This lack of financial certainty increases the financial risks for undertaking such projects, implying that they are less likely to be approved. Price guarantees or other incentives around reducing such risks could potentially help to reduce these risks.
- A lack of pipelines or bottlenecks with rail transport makes it harder for sites to get their products to market. Once product storage areas start to fill up, sites must reduce their production rates, and operate with less economic efficiency. At one plant, dropping production to 70% increases the amount of energy consumed per tonne of product produced by a factor of ~1.4. Thus, it is critical to address transportation bottlenecks.

## 5.5 COMPONENTS NEEDED TO ACHIEVE ENERGY INTEGRATION

Based on the messages heard from companies and the information obtained from reviewing other industrial parks around the world, a conceptual model emerged (Figure 9) which helps summarize the nature of the barriers to achieving greater energy integration in these two industrial areas.

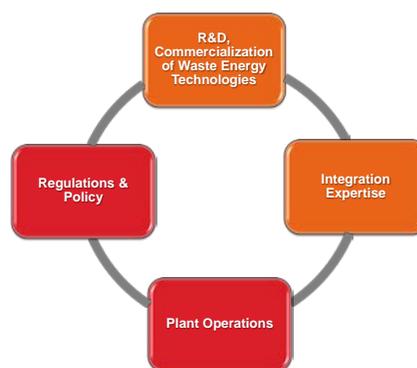


Figure 9: Conceptual model of the components needed to achieve greater energy and industrial integration in the two industrial areas.

The technical review (see the Appendix) indicated that many mature technologies exist which are being deployed elsewhere, and that further R&D work is proceeding around the world to improve these technologies and to develop new ones. Similarly, the expertise needed to install such technologies within plants exists around the world. Thus, the non-existence of technologies, or a lack of expertise on how to install such technologies are not the primary reason for the limited use of waste energies in the industrial areas reviewed within this study – although there are undoubtedly specific technological challenges which need to be solved for Alberta’s particular industries.

Instead, the primary barriers to greater energy integration in these regions seems to be more the result of current policy and regulations, coupled with plant operators who are averse to any technology which increases the risks of a plant shut-down; adds additional complexity, or has a low ROI compared to other possible investments.

## 6 HIGH-LEVEL EXPLORATION OF OPTIONS

---

Given the waste heat sources identified in Section 5, it is natural to ask; what are the best technologies for capturing the waste energy from these streams, and once the energy is captured how it could be used? Section 6.1 below gives a high-level overview of the waste heat recovery themes which are prevalent with current waste heat recovery technologies, while Section 6.2 summarizes some of the technical and economic limitations associated with waste heat recovery and reuse technologies. Additional details can be found in the Appendix. Finally, Section 6.3 discusses a number of options for using the waste heat in the three heat islands identified in this study.

### 6.1 OVERVIEW OF WASTE HEAT RECOVERY

Waste heat from industrial processes results from equipment inefficiencies and thermodynamic limitations on transferring heat. Waste heat is generally classified as low grade, medium grade and high grade based on the temperature of the stream carrying that heat. These temperature ranges are not defined rigidly and this study chooses to define them as: low grade below 230 °C, medium grade between 230 and 650 °C, and high grade above 650 °C. A number of thorough reviews have been done on waste heat recovery<sup>24</sup>, which show that heat recovery opportunities across these temperature ranges can be understood from three broad perspectives on how the waste heat is utilized:

1. **Waste heat can be recycled within the heating system** – including using it to preheat combustion air (thereby lowering fuel requirements), heating the load or charge being input to a process; or cascaded so that waste heat coming off of a high temperature process is used to heat another process requiring a lower temperature.
2. **Waste heat can be converted to electrical power** – which includes ‘conventional power plants’ which use steam turbines and generators, Organic Rankine Cycle, Kalina, Neogen (ammonia-water) type systems, and Stirling engines; and also thermo-electric power generation systems which convert heat directly into electricity.
3. **Waste heat can be recovered using an auxiliary system and transformed or transferred to other uses** – including using the heat for steam generation, water heating, space heating (including district heating), driving absorption cooling systems, providing energy for a thermo-chemical process, selling the heat to neighbouring sites, or for satisfying process heating requirements elsewhere in the plant.

The application of each of these methods is dependent upon the waste heat’s quantity, quality (temperature), composition (presence of particulates and corrosive species), temporal availability, location, and economics.

---

<sup>24</sup> E.g., US Department of Energy, Industrial Technologies Program; *Waste Heat Recovery: Technology and Opportunities in US Industry*. March 2008; Energy Design Resources; *Design Brief: Industrial Process Heat Recovery*. October 2009. Accessed January 20, 2014 at <http://energydesignresources.com/resources/publications/design-briefs/design-brief-industrial-process-heat-recovery.aspx>

## 6.2 TECHNICAL AND ECONOMIC LIMITATIONS TO WASTE HEAT RECOVERY

A number of common technical and economic limitations need to be considered in waste heat recovery and each is summarized below.

### **The quantity of available heat is limited by the laws of thermodynamics and physical properties of the fluids exchanging heat; the energy quality of waste heat is governed by its temperature**

The theoretical quantity of waste heat available is a function of mass flow rate and specific enthalpy as a function of temperature (temperature difference between the waste heat fluid temperature and the temperature of the heat exchanging cold fluid). However, the quality of waste heat, and therefore the practical amount that could be recovered, depends on the temperature of the hot fluid (among other factors). The rate of heat transfer is directly related to the heat transfer coefficient, heat exchange area and temperature difference. For a given heat transfer rate, a low temperature difference will mean a very large heat exchange area, and therefore an expensive heat exchanger.

### **Temperature and chemical composition of waste streams limits heat extraction**

A majority of the heat transfer applications involve heat exchange equipment where the hot and cold streams are physically separated by a material, which transfers the energy between the streams. The rate of heat transfer between the two streams is proportional to the temperature. The smaller the temperature difference between the streams, the greater the surface area required for heat exchange to take place - increasing the cost of the heat exchanger.

Temperature and chemical composition of the hot streams can also limit the amount of heat that can be captured. Flue gases may contain CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub>, H<sub>2</sub>S, volatile organic species and moisture, among other compounds. If the flue gas is cooled below the dew point of these constituents, the condensed vapours can cause corrosion of the heat exchange surface. Thus, heat exchangers are generally designed and operated at temperatures which are higher than the dew point of the oxidizing constituents, limiting the amount of energy captured.

High temperature streams, however, present an alternative set of challenges because of accelerated corrosion and oxidation at higher temperatures. For example, carbon steel and stainless steel both begin to oxidize at temperatures above 425 °C and 650 °C respectively. Also, since most metals begin to melt above 1,000 °C, they cannot be used for heat exchange applications above 1,000 °C. Instead steel alloys or composite materials (e.g., ceramic based) are used. The higher temperatures of the input stream can also mean that such materials are subject to greater thermal stress due to variation in the heat load supplied, leading to earlier material failure.

In summary, the evaluation of appropriate heat exchanger technologies must be considered on a stream by stream basis.

## **Process and accessibility constraints on waste heat streams can limit waste heat recovery**

A key challenge in trying to retrofit existing plants is that there may not be space around the waste heat stream to install the required heat exchanger equipment. Operational constraints on the parent processes may also limit the ability to install heat exchanger equipment since industrial processes are optimized for the main product and the installation of heat exchanger equipment could compromise process quality and control.

## **Economics of waste heat utilization need to be examined holistically from a systems perspective**

The economics of capturing waste heat is constrained and influenced by all of the considerations listed in this section and there are typically trade-offs among options. For example, while more heat could be captured by cooling flue gases below their dew points, the value of the heat captured may be offset by the need to use special corrosion resistant materials. Another example is that, although theoretically, the quantity of waste heat could be increased by reducing the sink temperature (increasing the temperature difference), the quality of that recovered heat will be poor and trade-offs will have to be made to provide more energy for the required cooling at the sink side of the system. Thus, it is critical that waste heat capture opportunities are evaluated holistically within the context and constraints of the process and site.

The ROI for systems depend on the scale and type of technologies being installed. Although publicly available information<sup>25</sup> exists on estimated capital and operating costs of waste heat recovery technologies, the validity of such estimates in the Alberta context is uncertain. However, these estimates do provide some benchmark costs for quick financial evaluation of waste heat utilization opportunities:

- Process recycling of waste heat (e.g. combustion preheating, charge preheating, heat cascading etc.): Temperature 200 °C or higher, 30-90% heat recovery, costs are \$32,000 – \$79,000 per GJ (\$30,000-\$75,000 per MM Btu) heat recovered, payback period typically 1-3 years, retrofitting required.
- Heat used for auxiliary requirements (e.g. steam generation, water heating, absorption cooling etc.): Temperature 120 °C or higher, 10-75% heat recovery, \$26,000 -210,000 per GJ (\$25,000-\$200,000 per MM Btu) heat recovered, payback period typically 1-5 years, requires an appropriate system which demands particular quality of heat.
- Waste heat to electricity (e.g. Organic Rankine Cycle, Kalina Cycle, etc.): Temperature 150 °C or higher, efficiency 10-25% but lower in many cases, \$2,500-\$3,500 per kW.

It is likely that a complete techno-economic evaluation of a waste heat opportunity would also involve comparing its techno-economics with that of a conventional fossil fuel based heat generation system. In that context, the continuing low price of natural gas in Alberta and the current carbon tax rate would most likely put the economics of the waste heat recovery project at a disadvantage.

---

<sup>25</sup> Thekdi, Arvind C. (August 2009), *Waste Heat Management Options: Industrial Process Heating Systems*, E3M Inc. Accessed January 25, 2014 at [http://www1.eere.energy.gov/manufacturing/pdfs/webcast\\_2009-0820\\_whmanage\\_phsystems.pdf](http://www1.eere.energy.gov/manufacturing/pdfs/webcast_2009-0820_whmanage_phsystems.pdf)

## 6.3 IDENTIFICATION AND EXPLORATION OF OPTIONS

Based on the review of waste heat capture and use technologies and the insights provided by other industrial experts, some ‘rules of thumb’ were suggested for how to go about looking for options to use waste heat:

1. Look for possible uses of the waste heat within the process.
2. Given that electricity is much easier and cheaper to transport than heat (i.e., transportation infrastructure for electricity just involves cables while moving heat requires pipes), look for opportunities to generate electricity with the waste heat streams.
3. Determine whether there is an opportunity to use the waste heat elsewhere on the site, such as heating buildings or tanks, or in some other process which may not have been considered by site engineers due to information and management silos which may exist.
4. Look for opportunities to move the heat outside the boundaries of the site.

The primary consideration driving these ‘rules of thumb’ are the high infrastructure costs associated with transporting heat (installation of pipes and pumps) and the above rules seek to minimize the need for such infrastructure. Given the large distances between industrial sites in the Strathcona and Heartland areas, and even the large distances between processes on individual sites, the above rules seem quite relevant to Alberta

### 6.3.1 POTENTIAL OPPORTUNITIES ACROSS ALL WASTE ENERGY ISLANDS

A number of opportunities are not unique to any of the energy islands and should be considered at all sites.

#### **Generate Electricity from Waste Heat Streams**

After trying to find uses for waste heat directly within the process, the next best option is to determine whether electricity can be generated from the energy source. Given the large amount of mid-grade waste heat identified in this study, the next step in assessing this opportunity is to obtain additional, more detailed information on the most promising waste streams and assess what the business case is for installing an Organic Rankine or Kalina Cycle machine to generate electricity. There may be opportunities to improve the business case by combining multiple waste heat streams to increase the scale of such plants, with heat coming from multiple streams on a given site, or (in a few situations) from streams on neighbouring sites.

#### **Pressure letdowns**

Given that large amounts of natural gas consumed in each of these industrial areas which is supplied at high pressures (likely between 5500 to 6900 kPa), further investigation and information is needed to determine how easily the pressure letdowns which are occurring could be used to generate electricity; and whether a viable business case can be made to capture such energy.

There may be similar opportunities to generate electricity based on the pressure differentials for stored natural gas liquids since the pressure differential between the pipeline and storage is ~10 MPa. Further investigation and information is needed to determine whether a viable business case can be created for trying to capture energy from this highly intermittent energy source.

### 6.3.2 STRATHCONA INDUSTRIAL AREA

The Strathcona Industrial area has a large amount of waste heat and also a number of opportunities, which seem unique to this particular geographic region.

#### High Temperature Energy Sources

Strathcona contains a large high-temperature heat source (~11.5 MW), which is coming from a single stack on one of the sites. The company has been actively trying to find uses for this heat source – ideally with a third party agreeing to operate a power generation system on site. To date, however, no suitable third party has been identified. It is unclear why this has not occurred and what barriers the company is experiencing.

#### COGEN Opportunities

One of the sites visited is already setup for COGEN, which could easily be installed on site. The advantage of having a COGEN operating on site is that it would increase the overall level of steam security – making it less likely that a site shutdown would be triggered due to an interruption in its regular steam supply. This opportunity has never been acted upon by the company given a limited market offsite for the steam generated.

#### Heating of Intermediate Product Tanks

At least one of the refineries in the area is known to heat tanks, which store intermediary products during the upgrading and refining process. Some of these tanks are currently heated with steam. There is likely an opportunity to capture waste heat sources from other locations on the site and use this energy to heat the intermediary product tanks. Further scoping of this idea will require that various site engineers determine the feasibility of heat capture on site and whether a viable business case can be made for changing how these tanks are heated.

#### Redevelopment Opportunities

In talking with various experts with a lot of experience about this geographic area, the team learned that the boilers on two sites are nearing the end of their life and will need to be replaced in the near future (i.e., ~ 10 years). Such future replacement opens up opportunities around COGEN and possibly even ‘sub-regional’ steam systems if ways can be found to locate other industrial sites close to these plants. Given that not all of the land is developed surrounding these sites (but is owned by various other companies), this may be possible in some cases. This is admittedly a long-shot opportunity, but given the time frame around replacing the boilers, there is sufficient time to further explore and evaluate this idea.

## District Heating Systems in Neighbouring Communities Does Not Seem Viable at Present

Given the large amount of low and medium temperature waste heat in this region, using such heat for district heating is an obvious option for redeploying this waste energy to a useful purpose. However, the two main challenges are the large distances between the heat sources and neighbouring municipal development; and that some of the surrounding municipal development is low-density single-family houses. If the surrounding development was higher density (e.g., multiple multi-storey apartments, or large shopping malls), then it could make sense to seriously consider this option. Further collaboration with potential municipalities that surround the Strathcona Industrial area is thus needed since the knowledge of this potential heating source may actually drive future development that can take advantage of this resource.

### 6.3.3 HEARTLAND NEAR FT. SASKATCHEWAN

While the least amount of waste heat was identified in this region, the larger opportunity may be to consider developing a regional steam system, which could serve sites closest to Fort Saskatchewan. A number of the companies were open to further discussions to strategically assess this option. This also opens up opportunities for COGEN and creating sufficient regional redundancy in steam supply thereby reducing the risks of steam failure below that presently found on individual sites. A reduction of such operational risks has value to the large industrial sites. Further, two light industrial areas are currently under development (the East Gate Business Park and Fort Industrial Estates) just to the east of the industrial sites included in this study. There may be an opportunity to include these yet-to-be developed sites as part of such a regional utility system. Provision of lower temperature heat to such parks could also, for example, support the processing of biomass in the region<sup>26</sup> and help to diversify the region's economic base.

### 6.3.4 HEARTLAND NEAR SCOTFORD

The sites within this island are relatively new and are also already highly integrated with each other. However, a large amount of future development is already underway or planned:

- The proposed Williams Energy propane dehydration plant is south-west of Shell Scotford Manufacturing and just across the North Saskatchewan River from Williams' Redwater Olefins Fractionator (which produces some of the propane needed by this future plant). The proposed plant will process an estimated 22,000 barrels per day of propane, and greatly expand production of polymer-grade propylene to ~500,000 tonnes per year. The facility is expected to be in service by mid-2017. There is potential to double capacity.

---

<sup>26</sup> Alberta's Industrial Heartland – Pre-Feasibility Scan of Potential Biomass Supply.  
[http://www.industrialheartland.com/images/stories/reports/prefeasibility\\_scan\\_of\\_potential\\_biomass.pdf](http://www.industrialheartland.com/images/stories/reports/prefeasibility_scan_of_potential_biomass.pdf)

- Veresen is proposing to build a 110 MW (maximum output) high efficiency, natural gas-fired cogeneration facility on the Williams Energy Propane Dehydration Facility south-west of the Shell Scotford Manufacturing Facility. By-product fuel from the Williams facility will be the primary fuel source at this cogeneration plant, and in turn Veresen will provide electricity and steam to the Williams plant.
- Air Products future hydrogen plant will produce 150 million standard cubic feet per day (MMSCFD) of hydrogen and will be connected to the hydrogen pipeline. The new plant is to be commissioned in the second half of 2015 pending regulatory approval, and will also supply steam to the Shell Scotford Manufacturing Centre.
- ATCO Power is proposing to build and operate a 400 MW natural gas-fired power generation station (the ATCO Heartland Generating Station) south-east of the Scotford Manufacturing Centre.

Since many of these future plants are already under construction or working their way through the regulatory approval process, it is likely too late to explore broader regional options around energy utilities for these specific plants. However, as there is still a lot of undeveloped land around these sites, and a strong desire to locate additional industrial sites in this region, it may be worth exploring how common utilities for energy or water that industrial operations could simply “plug into” might entice other industrial operations to locate within this area. Alternatively, the idea of developing integrated utilities which companies could plug into could be scoped out and further developed for the largely greenfield area across the North Saskatchewan River near Agrium and the North West Redwater Partnership. Regardless, developing this idea of “plug and play” industrial areas could help the government achieve its objectives of increasing economic development in the Heartland in a way which minimizes environmental impacts, in particular GHG emissions.

# 7 CONCLUSIONS AND RECOMMENDATIONS

---

## 7.1 CONCLUSIONS

The main conclusions from this study are:

- **A significant amount of mid and high-temperature waste heat exists across the companies, which participated in this study.** Assuming that 33% of the energy identified in low pollutant exhaust stacks and also coolers and compressors could be captured and repurposed, the resulting total 99 MW of waste heat (of different temperatures) is theoretically sufficient to heat 15,200 average homes, generate 5 MW of power (enough to power 5,100 homes), and would reduce CO<sub>2</sub>e emissions by ~151,000 tonnes.
- **The waste energy streams seem to be clustered on just a few industrial sites,** meaning that some sites had large amounts of waste energy, while others had very little. Given that companies self-reported all waste heat information following the “80-20 Rule” of focusing on large waste heat sources, it is unclear the extent to which such clusters are simply a result of the way in which information was obtained for this study. Regardless, the fact that sites with large amounts of waste energy exist means it should be easier to capture and reuse such energy than if it were distributed more evenly across sites.
- **Factors which make it less likely that companies will proactively try and address energy efficiency opportunities on their site or in combination with other sites include:**
  - The low price of natural gas;
  - Uncertainties around how government will set baselines for measuring future GHG reductions;
  - A lack of clarity around how GHG reductions could be shared between sites which jointly participate in a project (e.g., creation of low-pressure hydrogen pipeline);
  - The low ROI generally associated with energy efficiency initiatives means that companies will invest in opportunities which will have a more substantive impact on their profitability;
  - Increased complexities and production risks of installing unfamiliar technologies within their processes;
  - The complexities of trying to identify synergies and also setup bilateral agreement (e.g., around the supply of water, steam) between independent sites. Minimizing the risks of supply disruptions will increase costs, thereby making the economics of such projects even more challenging;
  - The need for companies to stay focused on their core operations, which is about producing products. Given that many companies are short of key staff, finding the time to even investigate opportunities can be challenging.

- **Having a neutral third party engage companies in this type of study is essential.** The social barriers to industrial energy mapping are far greater than the technical barriers. Building trust with industry to conduct such studies requires a neutral third party (i.e., not government, not a firm trying to sell technologies) with a proven track record of dealing with sensitive information, and who the companies can trust.
- **The approaches used successfully gained the trust of 16 companies operating on 17 sites who participated in this study should apply equally well in other industrial areas across the country.**

## 7.2 RECOMMENDATIONS

Key recommendations emerge which are critical to advancing this industrial energy mapping study to the next phase of activity needed to achieve the long-term objectives of greater energy efficiency and GHG reductions in these industrial areas.

1. **Create an “Industrial Cluster Management System” (ICMS)** to address the policy and regulatory barriers which are inhibiting greater energy integration in these industrial regions. Currently, Alberta is engaged in constructing an Integrated Resource Management System (IRMS) comprised of a system for environmental monitoring, cumulative effects evaluation, policy and planning, and regional land-use planning. A similar kind of system is needed to address the industrial challenges Alberta is facing. An ICMS is needed because achieving greater energy efficiency (and GHG reductions) in these industrial areas requires much more than simply adopting new technologies – it requires systems design thinking to create a new kind of eco-industrial environment which will facilitate the achievement of regional goals. The ICMS would:
  - a) **Deal with policy and regulatory changes needed to realize efficiencies through industrial integration** (e.g., expanded industrial systems designations, elimination of electricity feed-in tariffs, different types of incentives, or an increased carbon tax).
  - b) **Include an entity, which would act as an independent, third party intermediary between government** (e.g., Energy, AESRD, IAE, Economic Development, etc.), and industry. Such an intermediary would potentially have multiple roles including facilitating the creation and maintenance of shared infrastructure (e.g., around water, steam), identifying ways to increase the attractiveness of industrial areas to potential investors, coordinating infrastructure planning and development, identifying opportunities for third party service providers (e.g., around waste products such as heat), and overseeing land management activities.
  - c) **Contain a dedicated program focused on addressing the social and technical innovation barriers these industrial areas are facing;** to improve cost effectiveness, productivity, diversification and global competitiveness. While industrial areas like Strathcona and the Heartland are vital to the economic health of the province, there is presently limited appreciation of the social and technical barriers these areas face, and thus limited understanding of how best to address such issues. Possible focus areas for such a

program might include: finding ways to break down information barriers between companies around wastes or other potential symbioses, removing the risks associated with trying to achieve greater industrial integration, reducing the risks of companies implementing new technologies on their sites, strategically identifying the best ways to improve efficiencies of the region, or scoping out how these areas could be strategically positioned to attract other industries to increase industrial diversity. Creating such a program would be a great opportunity to involve all aspects of Alberta's innovation system (academia, funders, research technology organizations, and the private sector) with the goal of making Alberta's industrial areas world leaders in eco-industrial development (i.e., globally competitive economically and environmentally).

- d) **Evaluate business cases and operational models for opportunities** such as regional utilities for steam or water. How would having such utilities make it easier to attract companies? How might such a utility be governed? How would it operate (P3, private utility, etc.) and be able to scale with increasing demand while ensuring high reliability? Etc.
  - e) **Engage with surrounding municipalities to explore the potential for district heating.** The lessons learned from such an evaluation could inform how industrial and municipal development can be planned so they are more synergistic in the future. This could lead to best practices on how to better enable the use of waste energy when developing greenfield sites.
  - f) **Enable continuous learning and improvement** in how Alberta goes about creating globally competitive industrial areas where companies want to locate.
2. **Publicize the results of the study** to enable identification of other potential options and ideas, which were not identified. For example, private sector companies exist which are experienced in operating ORC and Kalina cycles as third parties on industrial sites. Making companies aware of such opportunities is a first step to implementation of waste heat capture and re-use technologies.
  3. **Scale the work** by applying the approach and methods to other industrial areas in Alberta and the rest of Canada to determine whether other parks are facing similar kinds of barriers around waste heat utilization.

## 8 CLOSING

---

The results of the Community Integrated Energy Mapping Feasibility Study indicate a positive value proposition for further industry and government engagement in actions that will reduce GHG emissions, improve competitiveness, enhance efficiency, and contribute to economic diversification. However, realizing this full value proposition in Alberta will require much more than simply getting technologies adopted on industrial sites - it will require systems design thinking by all stakeholders to create a new kind of self-sustaining social-technical industrial environment.

To that end, the study supports the Government of Alberta's current work in developing policies that will create stronger industrial clusters, and also has created interest within Alberta's Innovation System to identify any major technology gaps around capturing and using low-grade waste heat in Alberta's industrial landscape. These next steps will help further the collaboration between industry, government, and the innovation system by providing the foundation to fully realize the value proposition in the future.

# APPENDICES

## 9 APPENDIX: PROJECT BACKGROUND

---

### 9.1 PROJECT HISTORY

The genesis of this study grew out of a series of projects carried out independently by AITF and C3 beginning in 2009. During that year AITF used internal funds to undertake a small feasibility study focused on mapping the energy demands of industries in Alberta. The key learnings from this project included how difficult it was to get industry support for studies of this kind. Based on these findings, AITF began working on a white paper in the summer of 2010 laying out the value proposition for mapping energy supply and demand across the province and making this data available through some kind of data portal. This white paper was used to engage with C3 and the Alberta Urban Municipalities Association in October of that year.

Around the same time C3 was heavily involved in conducting a Conservation Potential Review for the Province of Alberta, designing and delivering a host of demand-side management projects and engaging the industrial sector regarding their perceptions of energy efficiency.

Combining the collective efforts of C3 and AITF to address energy mapping was a logical outcome of these independent efforts. The partners agreed that C3 should be the overall project lead or face of the collaboration.

In March 2011, the project team met with Alberta's Industrial Heartland Association. This led to a tour of the Heartland region near Fort Saskatchewan in July 2011 to explore the idea of energy mapping. The tour included representatives from the Alberta Government (Environment, Finance and Enterprise, and Energy). The concept of energy mapping is presented to industry representatives (DOW, Agrium, Sherritt, Praxair, Shell, and Keyera Energy) and municipal representatives from the five municipalities bordering the Heartland who demonstrated their interest to continue to take the concept to the proposal phase.

In October 2011, the project team submitted a Letter of Interest to NRCAN's ecoEII call for proposals. The team is invited to submit a full proposal in January 2012.

NRCAN accepted the proposal, but agreed to fund only an initial feasibility study focused on demonstrating that sufficient waste heat actually existed within the region before proceeding with some of the additional Phases outlined in the original proposal. The project team submitted a revised proposal to NRCAN for just the feasibility study component in July 2012 and continued to engage governments and industry regarding defining in-kind support from industry for this project.

A contract between NRCAN and C3 was completed by April 2013 and between C3 and AITF by June 2013 and work began on the project.

## 9.2 PROJECT OVERVIEW

### Project Goals

The goals of this project were to:

- **Estimate the types, quality, and quantity of energy** across participating sites in the southern part of Alberta's Industrial Heartland (the target area) for the purpose of examining the feasibility and underlying value proposition for greater energy integration, primarily around waste heat sources, across the larger Heartland area;
- **Build trust among participants** and the larger Heartland membership to enable subsequent phases of work to proceed to achieve the above goal;
- **Define the business case** for expanded energy mapping other industrial, commercial or other regions (i.e. Municipalities) across Canada

### Project Overview

Achieving these goals were accomplished by:

- **Engaging with companies to address concerns** (e.g., confidentiality) around participating in such a feasibility study;
- **Securing access to high-level data** on energy supply and demand at sites along with information on energy input and output for major processes at these sites in a manner which minimizes the resources companies must devote to this initial feasibility assessment;
- **Identifying potential technologies**, which could be used to recover surplus energy, store it, and transfer it between sites or even outside the boundaries of the Heartland area to enable development of a high-level business-case for greater energy integration.
- **Identifying potential implementation recommendations.**

The specific steps in this project included:

1. **Initial scoping of site processes and energy requirements based on publically available information** about the processes occurring within each participating company's site (e.g., filings with Alberta's Energy Resources Conservation Board; Environment and Sustainable Resource Development; US DOE Industrial Energy Use databases; etc.).
2. **Engaging company representatives (process managers, site engineers, etc.) to validate the information obtained from public sources**, explain what kinds of information and data are still required, address any confidentiality or other concerns companies may have; and obtain the data and information required for this feasibility assessment.

3. **Standardizing and synthesizing the information on energy types, quality, and quantity across sites.**
4. **Creating the value proposition for proceeding with subsequent phases of work** aimed at achieving greater energy efficiency through integration within the larger Heartland region.

**Deliverables:**

- **Energy integration feasibility report** estimating the types, quality, quantity of energy available across participating sites, and estimates on how much of this energy can be recovered economically with available technologies;
- **Approach or framework for protecting confidential information** or IP while still enabling the project team to work with potentially sensitive company data and information, and report aggregate information back to funders and other companies;
- **Review of best practices and leading technologies** used for energy integration at similar industrial parks.

**Value to Companies in Alberta’s Industrial Heartland**

- An assessment of low-grade and other waste-heat capture opportunities at company facilities;
- An enhanced value proposition for greater energy integration/re-use leading to greater value creation within the region (e.g., informing future greenfield or brownfield developments);
- A better understanding of GHG reduction and energy efficiency opportunities;
- Companies will be featured in communications associated with this project.

**Project Schedule**

The project took 12 months to complete

Project Design	6 weeks
Review of Similar Industrial Parks	10 weeks
Industry Stakeholder Engagement	40 weeks
Technology Review	8 weeks
Synthesis of Integration of Site Information and Data	6 weeks
Recommendations and Conclusions	4 weeks
Reporting and Communications	4 weeks

# 10 APPENDIX: STAKEHOLDER ENGAGEMENT

---

The stakeholder engagement process proved to be very successful and demonstrated a strong interest level from industry and others. Over the course of the project the number of companies participating grew from 6 at the project approval stage to 16. In addition the website received over 350 visits during an 8 month period of the project and interest in conducting similar studies in other regions came from 6 different areas, including the State of Wyoming. Proposals were submitted to The City of Edmonton and the Canadian Oil Sands Innovation Alliance.

## 10.1 OUTREACH

The Community Integrated Energy Mapping Project team hosted numerous stakeholder events, workshops and site meetings with the companies participating in the project; managed a website and hosted media relations. Activities included:

- Project Orientation Session – July 4, 2011
  - This public workshop gathered all interested government, corporate and industrial parties for an afternoon session to explore the potential for the project.
- Alberta’s Industrial Heartland Annual General Meeting presentation – May 27, 2013
  - This presentation provided a project overview to the AIHA membership.
- Industry Kick-Off Meeting – September 12, 2013
  - This session provided an orientation to the companies involved and launched the project. An overview of the questions and discussion are in Appendix 10.2.
- Data Presentation and Discussion – February 27, 2014
  - This workshop provided an interactive overview of the data that emerged from the study and an orientation to the technology solutions under consideration.
- Industry Site Meetings
  - Numerous site meetings occurred with various industry participants in order to validate their data, and to investigate waste heat capture and re-use opportunities.
- Media articles
  - Media pieces appeared in a number of local, regional and U.S. newspapers.
- Website
  - The Project team created and maintained a project website, <http://heartlandenergymapping.c-3.ca/> which is now closed. Future outreach will be through CMC’s website, <http://www.cmcghg.com/resources/special-projects/>

## 10.2 INDUSTRY KICK OFF MEETING SUMMARY

### Questions and Comments from the Heartland Energy Mapping Study Stakeholder Kickoff Meeting

September 12<sup>th</sup> 2013

#### General Comments

- Some companies mentioned that they are already developing waste energy recovery plans for their sites and thus it would be great if this study could help them find other regional waste heat synergies to complement these plans.
- When the project team comes on site and meets with site experts, the team needs to emphasize that this study is **not** about doing an energy audit, nor is it about trying to improve site processes which have already been analyzed and optimized. Instead, the team needs to emphasize that this study is about trying to identify regional energy integration opportunities related to energy use and waste heat generation.

#### Questions

- **Are we modelling this study after the experience in Europe where this is already happening?:**
  - A: While this study has been informed by work happening around the world, we think that unique aspects of the current study are that it has a regional focus and considers not simply the amount of energy, but also energy types (electricity, natural gas, heat, steam, petroleum, etc.), energy quality (i.e., the temperature of a waste heat stream), and, finally the demand/production variability of these streams. The current study is also reviewing similar industrial parks around the world to get ideas on how these parks have pursued energy integration.
- **Is this project iterative? As the Heartland expands, will this study be repeated?:**
  - A: At present, we envision that the current study in its present form will only be done once. We hope that the current study will illuminate economically viable opportunities, which could be evaluated in greater detail in the future. For example, this study might inform some of the concepts for the development of eco-industrial clusters in Alberta.
- **Is the project team interested in accounting for seasonality in the data provided?:**
  - A: We want to try and account for temporal variability in the information collected as best we can. Understanding how energy flows vary will be important to ensure that energy integration options proposed are robust and can accommodate such variability. However, the project's ability to account for seasonality would be impacted by the quality and consistency of information provided.
- **How will you deal with the reality that our high and low-grade waste heat all gets mixed together in a single cooling water stream? :**

- A: We would be interested in understanding the quantity and quality of these separate waste heat streams, and the operational issues likely associated with trying to un-mix these streams. In some cases there may be potential here, in other cases it will be clear that this would not be possible operationally or economically. The goal of this study is to identify potential energy integration opportunities across sites so we can then identify where the most economically viable opportunities exist.
- **Is the team interested in the fuel gas being pushed out of flare stacks?:**
  - A: We are interested in ALL major energy flows into and out of a site, including fuel gas being pushed out of a flare stack. While we may not be able to identify how best to use a particular energy source, the advances in technology that are occurring may open opportunities in the future.
- **Since the team is first pulling publically available information, will the team show us what public data they have so we don't waste time pulling information you already have?:**
  - A: We will provide the site representatives with the public information we have about a site as a way to start the conversation around improving this site information.
- **To make this easier, could you provide us with appropriate templates so we have a better idea what data you are looking for? For example, for the major processes operating on our site, flare stacks, compressors, electrical, etc.:**
  - A: We will attempt to provide such templates when we communicate any public information we have on a site back to the site representatives before we arrange a site meeting.
- **How will the data be managed? Could Greenpeace get access to info through FOIP and then issue a report outlining who the high waste heat emitters are?:**
  - A: We will not disclose or make it possible to identify energy flows of individual companies or sites. Thus, all information reported to NRCan, GOA and the public will be aggregated across a geographic region. We should also stress that both C3 and AITF are experienced in dealing with proprietary information.
- **Since some companies will require a non-disclosure agreement, can we send out an NDA template for review to help speed the process of getting this NDA in place?:**
  - A: An NDA template is attached. As time is of the essence in this project, we are keen to get these NDAs done as soon as possible for any company, which requires them.
- **Will the outcomes of this study address potential energy integration opportunities in the Heartland and how these might be pursued?:**
  - A: Once we have obtained the energy information, our goal is to use this information to identify a number of potential energy integration opportunities and then screen these opportunities in terms of economic, technical, environmental, and regulatory policy factors.

- **Putting in infrastructure to handle waste heat (district heating) or other energy utilities could take many years and also has implications with regards to current regulatory requirements. Has the provincial govt expressed interest in providing support for infrastructure or technical upgrades and are they aware of the regulatory changes required to make this occur? :**
  - A: The provincial government is currently reviewing a variety of options for enhancing economic development in Alberta’s industrial parks. One option being considered is focused on ways to enhance eco-industrial clusters. This might involve creating an energy utility (e.g., for steam) so that companies could simply connect to the utility instead of producing that particular form of energy on-site. Whatever option the provincial government decides to pursue will be informed by the outcomes from this study.
  
- **In planning for integrated energy systems, the challenges are that massive infrastructure changes are required (e.g., cooling towers, stacks etc.) and also that industrial sites continually change and evolve (new processes being added, old ones shut down etc.). In such a context, how do we ensure that we do not regret any of the infrastructure changes contemplated?:**
  - A: At this stage, we do not claim to have the answer to this question. However, by reviewing other industrial parks around the world which are similar to the Heartland and which have also confronted the same issue in pursuit of greater energy integration within their park should provide some insights in how to address this challenge in Alberta.

# 11 APPENDIX: DATA TEMPLATES

It became clear very early in the project that there was a high degree of concern for how sensitive proprietary data would be managed; what kinds of data would be requested; who would have access to that data; and how it would be reported. In an effort to manage these concerns, the project team developed data templates that communicated the types of data required, ensured every company was approached in the same fashion, and clarified how data would be aggregated and reported.

## 11.1 DATA CAPTURE TEMPLATES

The templates used to request information from participating companies are included in the sections below.

### 11.1.1 ENERGY INPUTS

The information the project team tried to obtain included:

- **Description of the major energy types used** (typically natural gas, steam, refinery gas, electricity, petroleum coke, dilbit, field grade butane, hydrogen);
- **Approximate amount used** (e.g., MJ over a day);
- **Description of how the energy is used** (e.g., process heating to 250 °C);
- **Description of the variability in demand** (e.g., over a day or seasonally);
- **Other comments.**

Many participating companies were very sensitive about disclosing information on the energy inputs to their sites. However, it was possible to confirm the major fuel types used on the site. Across both the Heartland and Strathcona industrial areas, natural gas was by far the largest fuel consumed for any type of heating or combustion. Other major energy inputs include: electricity, petroleum coke, refinery fuel gas, dilbit, field grade butane, and hydrogen.

### 11.1.2 EXHAUST STACKS

- Covers any kind of exhaust stack on site, focusing on the major stacks.
- Moisture content can be computed if the fuel source and combustion process are known.

ID or Description	Fuel Source Type	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temp (°C)	Moisture Content (vol %)	Potentially Viable in terms of pollutants? (Y/N)	Comments

### 11.1.3 COOLERS

- The goal is to get a rough estimate of how much energy is being given off by these coolers, and also the energy quality (i.e., temperature) of the stream being cooled.
- Note that input and output temperatures refer to the stream that is being cooled – not the air passing through the cooler which is absorbing the rejected energy.
- There is some redundancy in the variables requested.

					Only One of These Needed		
ID or Description	Source (approx. where stream originates on site)	Stream Input Temp (°C)	Stream Output Temp (°C)	Flow Rate of Material through Cooler (kg/s)	Specific Heat Capacity of Liquid (J per kg K)	Energy rejected (kW)	Comments

### 11.1.4 COMPRESSORS

- The goal is to get a rough estimate of how much energy is being given off from the compressor, and also the quality (i.e., temperature) of the heat given off.
- Heat may be rejected by cooling the compressed gas, which is the focus of this table.
- If a wet screw type of compressor is used, the oil absorbs heat from compressing the gases, and the oil is then cooled. The variables are similar, but in this case we would be interested in the temperature of the oil before and after cooling.

					Only One of These Needed		
ID	Source	Gas Temp before cooling (°C)	Gas Temp after Cooling (°C)	Flow Rate of gas through Compressor (kg/s)	Specific Heat Capacity of gas (J per kg K)	Energy rejected (kW)	Comments

## 11.2 CALCULATION OF WASTE ENERGIES

### 11.2.1 GENERAL EXHAUST GAS

The data obtained from facilities consisted of the rate of flow of the exhaust gases, the overall stack dimensions, the temperature of the exhaust gas, and knowledge about the fuel source. The energy vented to the atmosphere includes sensible heat in the hot gases and latent heat in the water vapour, which is a product of combustion.

For natural gas fired boilers and heaters where detailed information on stack gas composition is not available, the gas composition and available heat was estimated based on an ASPEN model assuming:

- 10% excess air and complete combustion of methane to CO<sub>2</sub> and H<sub>2</sub>O this translates to approximate stack gas composition of:
  - O<sub>2</sub> 1.53%
  - N<sub>2</sub> 69.32%
  - H<sub>2</sub>O 19.75%
  - CO<sub>2</sub> 8.56%
  - Ar 0.83%
- The lowest practical stack temperature without condensing is 120 °C

To calculate potential energy available if stack gas is cooled to 120 Deg. C (i.e., the sensible heat from cooling) involves two steps:

- Use ideal gas law to convert volume flow at actual stack conditions to volume flow at 120 °C  
e.g. flow at 120 °C = flow at T<sub>s</sub> (120+273)/(T<sub>s</sub> +273)
- Energy (kW) = (1.0583 x T<sub>s</sub> - 127) x flow in m<sup>3</sup>/s at 120 °C

Where T<sub>s</sub> is the temperature of the stack.

Additional energy is present as latent heat in the water vapour as a result of combustion. Water vapour concentration will vary widely depending on fuel and amount of combustion excess air.

For natural gas fuel with 10% excess air, to calculate potential energy available if stack gas is cooled from 120 °C to 40 °C:

- Convert volume flow at stack conditions to volume flow at 120 °C
- Energy (kW) = 280 x flow in m<sup>3</sup>/s at 120 °C

Unless otherwise noted, the above approach is used for any combustion stack when reporting on a site's waste energies.

## 11.2.2 GAS TURBINES

For natural gas fired gas turbines (without duct burners) where detailed information on stack gas composition is not available, the gas composition and available heat was estimated by:

- Assuming 200% excess air and complete combustion of methane to CO<sub>2</sub> and H<sub>2</sub>O
- This translates to approximate stack gas composition of:
  - O<sub>2</sub> 13.08%
  - N<sub>2</sub> 73.30%
  - H<sub>2</sub>O 9.42%
  - CO<sub>2</sub> 3.32%
  - Ar 0.83%
- Assume that lowest practical stack temperature without condensing is 120 °C

### Sensible Heat from cooling stack gas to 120 C

To calculate potential energy available if stack gas is cooled to 120 °C:

- Use ideal gas law to convert volume flow at actual stack conditions to volume flow at 120 °C  
e.g. flow at 120 °C = flow at T<sub>s</sub> (120+273)/(T<sub>s</sub> +273)
- Energy (kW) = (1.0103 x T<sub>s</sub> – 121.5) x flow in m<sup>3</sup>/s at 120 °C

T<sub>s</sub> is the temperature of the stack.

### Sensible and Latent Heat

Additional energy is present as latent heat in the water vapour present as a result of combustion. Water vapour concentration will vary widely depending on fuel and combustion excess air.

For natural gas fuel with 200% excess air, to calculate potential energy available if stack gas is cooled from 120 °C to 40 °C :

- Convert volume flow at stack conditions to volume flow at 120 °C
- Energy (kW) = 105 x flow in m<sup>3</sup>/s at 120 °C

### 11.2.3 PETCOKE PYROLYSIS

The gas composition and available heat contained in the stack gas was estimated by:

- Assume carbon is the fuel
- Assume 20% excess air and complete combustion of carbon to CO<sub>2</sub>
- Add additional water to reach the reported 12% by volume in the stack gas
- This translates to approximate stack gas composition of
  - O<sub>2</sub> 3.7%
  - N<sub>2</sub> 68.6%
  - H<sub>2</sub>O 12%
  - CO<sub>2</sub> 14.8%
  - Ar 0.83%
- Assume that lowest practical stack temperature without condensing is 175 °C to prevent condensation of corrosive compounds.

#### Sensible Heat from cooling stack gas to 175 °C

To calculate potential energy available if stack gas is cooled from 1037 °C to 175 °C:

- Calculate gas flow rate at 1037 °C from stack diameter and gas velocity
- Energy (kW) = 287 x flow in m<sup>3</sup>/s at 1037 °C

#### Sensible and Latent Heat

Additional energy is present as latent heat in the water vapour present as a result of combustion. Water vapour concentration will vary widely depending on fuel and combustion excess air.

For coke combusted with 20% excess air and a stack water vapour concentration of 12%, to calculate potential energy available if stack gas is cooled from 175 °C to 40 °C:

- Calculate gas flow rate at 1037 °C from stack diameter and gas velocity
- Energy (kW) = 60.7 x flow at 1037 °C in m<sup>3</sup>/s

## 11.2.4 SITES PROVIDING NATURAL GAS FLOW RATES

Given that a few sites provided us with natural gas flow rates and exhaust temperatures instead of exhaust gas composition information, the energy in the exhaust stacks includes the sensible heat in the hot gases and latent heat in the water vapour product of combustion. For natural gas fired boilers and heaters where detailed information on stack gas composition is not available, the gas composition and available heat was estimated by developing an ASPEN model which assumed:

- 10% excess air and complete combustion of methane to CO<sub>2</sub> and H<sub>2</sub>O this translates to approximate stack gas composition of:
  - O<sub>2</sub> 1.53%
  - N<sub>2</sub> 69.32%
  - H<sub>2</sub>O 19.75%
  - CO<sub>2</sub> 8.56%
  - Ar 0.83%
- That lowest practical stack temperature without condensing is 120 °C

Knowing the flow rate of fuel in SCFH, to calculate potential energy available if stack gas is cooled to 120 °C (sensible heat from cooling stack gas to 120 °C) is given by:

$$Energy (kW) = (0.0001323 \times T_s(C) - 0.0159) \times (fuel\ flow\ in\ SCFH)$$

Where T<sub>s</sub> is temperature of the stack in °C.

Additional energy is present as latent heat in the water vapour present as a result of combustion. Water vapour concentration will vary widely depending on fuel and combustion excess air.

For natural gas fuel with 10% excess air, to calculate potential energy available if stack gas is cooled from 120 °C to 40 °C, the amount of sensible and latent heat present is given by:

$$Energy (kW) = 0.0349 \times (fuel\ flow\ in\ SCFH)$$

### 11.2.5 ADDITIONAL RESULTS - LOW POLLUTANT EXHAUST STACKS, LATENT AND SENSIBLE HEAT (COOLING FROM 120 TO 40 °C)

Low pollutant exhaust streams were also cooled from 120 to 40 °C to estimate the amount of latent energy available from the condensation of water in the exhaust gases. This calculation is largely for theoretical purposes because there would be all kinds of operational challenges associated with cooling exhaust streams to such a low temperature, coupled with the challenge of how cooling down to 40 °C could ever be accomplished in practice.

Figure 10 shows the amount of energy released from the low pollutant exhaust streams from cooling each stream from 120 to 40 °C classified by the amount of energy rejected, and also the original temperature of the stream before any cooling. Further cooling of the hottest stream in Strathcona from 120 to 40 °C would release ~2 MW of energy, while cooling the mid-temperature streams in Strathcona would release ~29 MW, and ~109 MW from the low temperature streams. In the Heartland, further cooling of the mid temperature streams would release ~31 MW, while further cooling of the low temperature streams would release 213 MW of energy.

Figure 11 is a scatter plot of the rejected energy from cooling the streams to 40 °C relative to the original temperature of the stream before any cooling. As found with just sensible heat, the main sources of rejected energy are clustered across just a few sites.

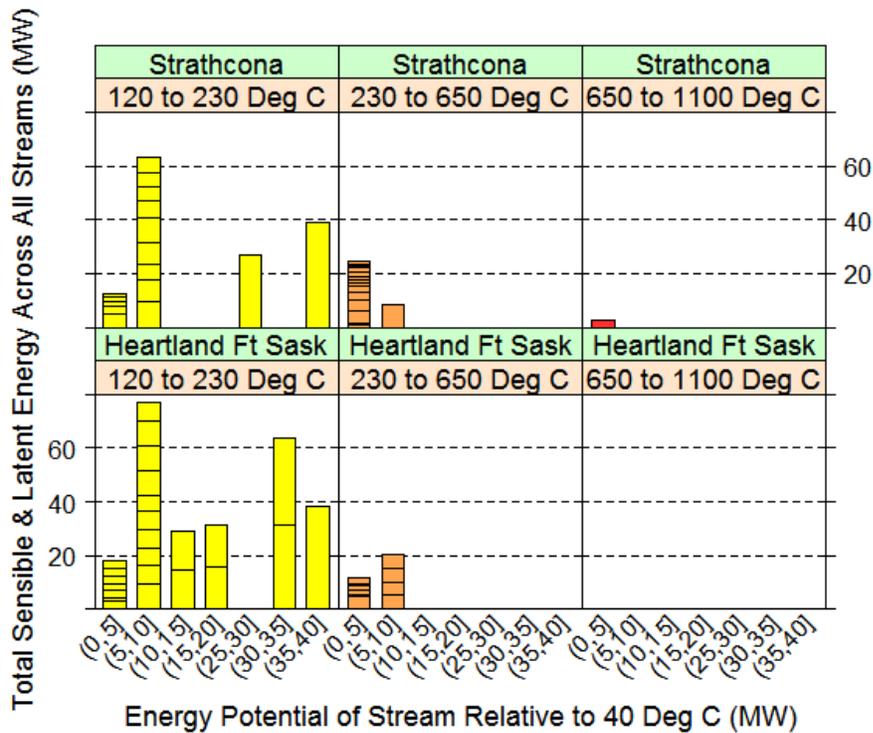


Figure 10: Low pollutant exhaust streams where the total rejected latent and sensible energy (MW) is computed relative to cooling each stream from 120 to 40 °C. Streams are grouped by their size after cooling from 120-40 °C (e.g., 0-5, 5-10, etc. MW) and original temperature (i.e., before any cooling) across the two industrial areas. Lines within each bar show the separate energy streams of the particular size category.

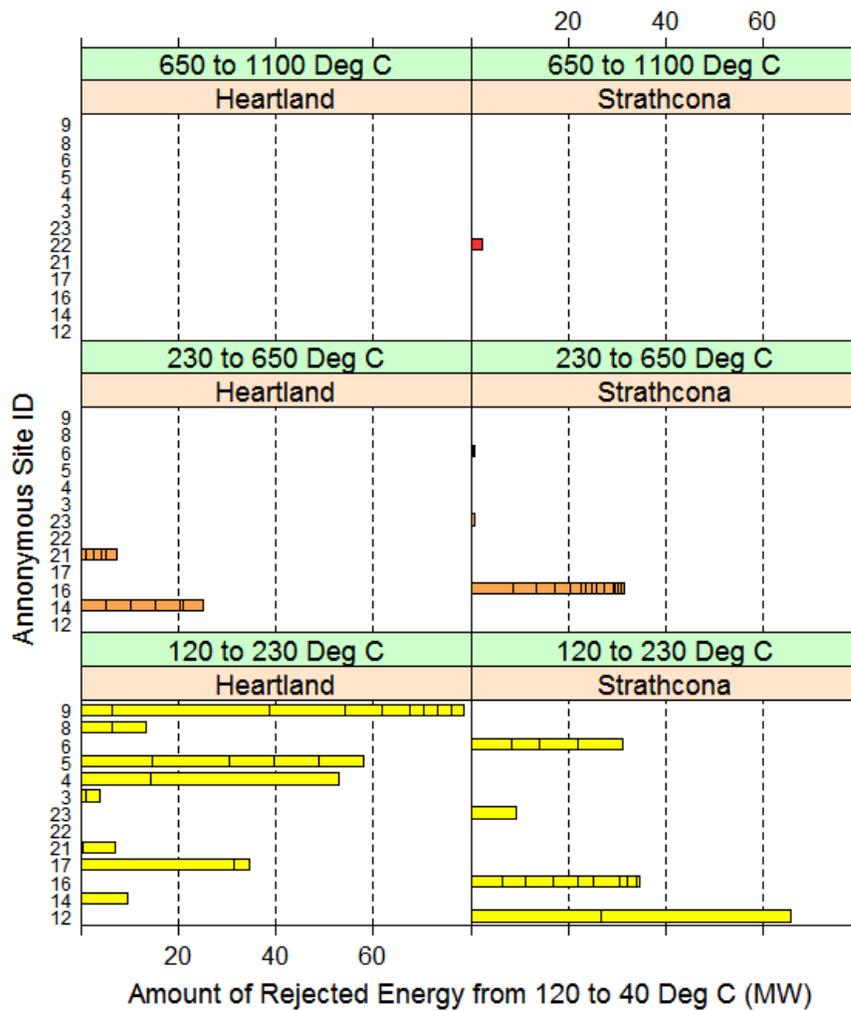


Figure 11: Low pollutant exhaust streams grouped by their originating site across the two industrial areas and also the original temperature of the stream before any cooling. An anonymous site ID (different from that in Figure 5) has been used to maintain anonymity of the companies. The total rejected latent and sensible energy (MW) is computed relative to cooling each stream from 120 to 40 °C. Lines within each bar indicate the sizes of the waste exhaust streams within each site.

## 11.2.6 ADDITIONAL RESULTS - HIGH POLLUTANT EXHAUST STACKS – SENSIBLE HEAT (COOLING TO 120 °C)

The following section includes information on the amount of heat rejected by high-pollutant exhaust stacks, stacks where the temperature cannot be lowered due to regulatory requirements, or stacks with other risks, which prevent such temperature reductions. Including such information provides an indication of the potential waste heat recovery opportunities if alternative, viable technology solutions could ever be found to deal with these issues.

For high pollutant streams greater than 1 MW in size with a temperature between 230 and 650 °C, Strathcona had ~2 MW of such rejected energy while the Heartland had ~39 MW (see Figure 12). No streams between 120 and 230 °C were identified in Strathcona, while the Heartland had ~28 MW rejected energy in such streams. The lack of data for Strathcona is likely a combination of sites choosing not report such streams given that we asked site-experts to apply the 80-20 rule and focus on significant waste energy streams, and also the different industrial make-up of this area relative to the Heartland.

Similar to what was found for the low-pollutant streams in the report, a few sites had the vast majority of the rejected energy from high-pollutant streams (see Figure 13). However, given that companies self-reported this information, it could be that high-pollutant streams (and the amount of energy shown to be rejected from such streams) has been underreported.

The scatter plot of stream size versus the temperature of the stream (Figure 14) indicates that most of the high pollutant streams reported are generally rather small in size, even though their temperatures can be quite high.

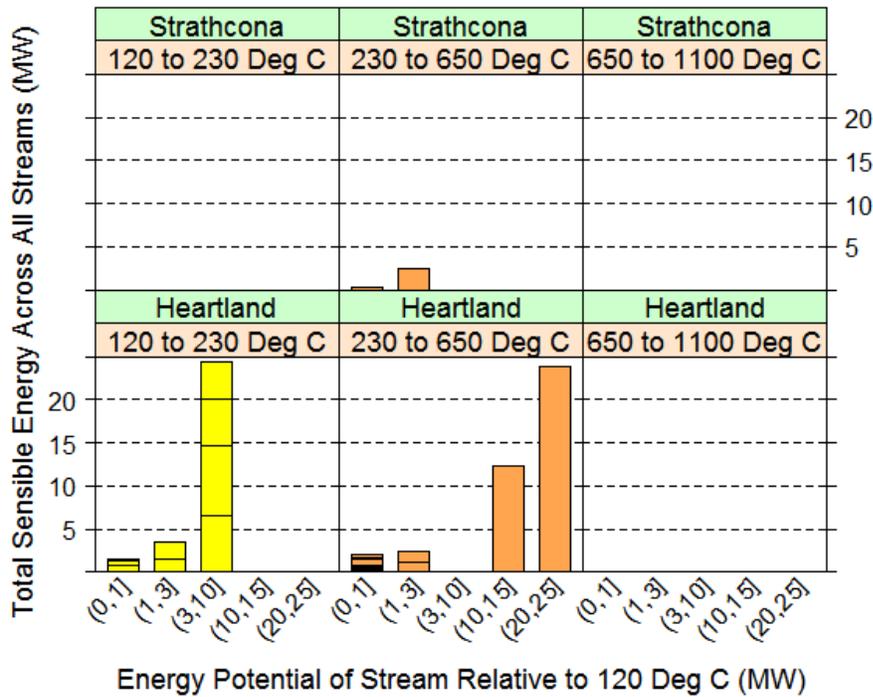


Figure 12: High pollutant exhaust streams grouped by their size (e.g., 0-1, 1-3, 3-10 MW) and temperature across the two industrial areas. The total rejected sensible energy (MW) is computed relative to cooling each stream to 120 °C. The horizontal lines within each bar represent individual waste energy streams.

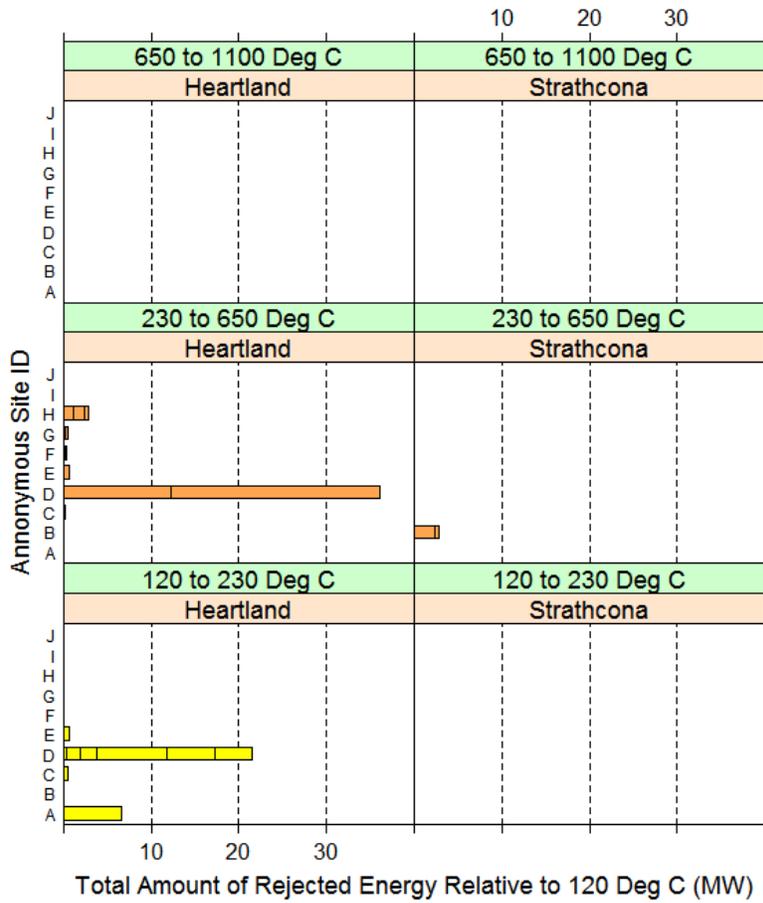


Figure 13: High pollutant exhaust streams grouped by their originating site across the two industrial areas and also the original temperature category of the stream. An anonymous site ID has been used. The total rejected sensible energy (MW) is computed relative to cooling each stream to 120 °C. The lines within each bar indicate the sizes of the waste energy streams within each site.

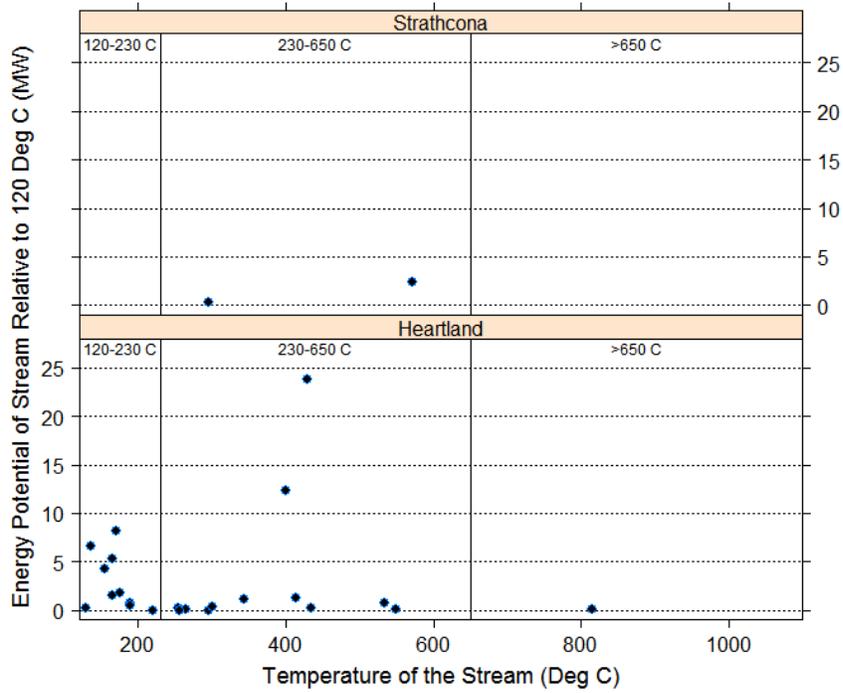


Figure 14: Estimated rejected energy of high pollutant exhaust streams relative to cooling the stream to 120 °C relative to the original temperature of the stream across the two industrial areas.

# 12 APPENDIX: REVIEW OF OTHER INDUSTRIAL PARKS RESULTS

---

## 12.1 CASE STUDIES: EXAMINATION OF BEST PRACTICES

When narrowing down the case studies to highlight, we attempted to select projects of particular relevance to potential waste heat project opportunities in AIH. Given waste heat capture and use opportunities at AIH may be either retrofit or potentially new build opportunities, we attempted to select both types of case studies. We also attempted to choose international best practices examples that included the following elements:

- Occur in the oil and gas sector including producing and processing oil, gas, and petrochemicals;
- Multiple companies involved in the project(s).

### 12.1.1 GÖTEBORG ENERGI DISTRICT ENERGY SYSTEM

**Key Energy Mapping Interests:** Highly innovative waste heat energy project involving multiple industrial (oil and gas industry) and municipal waste heat sources used to heat a municipality.

**Location:** Göteborg, Sweden

**In-service date:** 1953

#### **Technology Description (and timeline):**

- 1953 – Sävenäs combined heat and power plant begins servicing a district energy system delivering heat to the municipality;
- 1972 – City’s waste incinerator delivers heat to the district heating system;
- End of the 1970’s – Eight large “district heating islands” are linked together, waste heat from Shell’s oil refinery and waste heat from treated waste water (captured by a heat pump) are fed into the district system;
- 1988 – Natural gas, as opposed to oil, is first used in the combined heat and power plants (that provide waste heat to the district heating system);
- 1995 – Neighbouring municipality, Partille, join the district heating network;
- Mid 1990’s – District cooling is delivered to customers through a process called absorption whereas waste heat is converted to cooling;

- 1997 – Preem oil refinery begins delivering waste heat to the system;
- 1998 – Högsbo natural gas power and heating plant is built providing additional waste heat to the district energy system;
- 2003 – What was previously a natural gas hot water boiler feeding the district energy system is now heated by wood pellets;
- 2006 – Rya natural gas combined heat and power plant is opened (which provides waste heat to the district heating system);
- 2011 – 1950’s cogeneration plan is shutdown;
- 2013 – Gasification plant opened (Göteborg Energi, 2009).

District heating grid is larger than 1000 kilometers.

### **Preem Göteborg Oil Refinery**

The delivery of waste heat occurs via hot water with the supply temperature of 130 °C and a return temperature of 90 °C. The heat displaces consumption of 14,900 m<sup>3</sup> fuel oil and 40,000 tons CO<sub>2e</sub>.

For Göteborg Energi, the delivery of the waste heat takes place via hot water with the supply temperature of 90°C and a return temperature of 50°C. In 2008, 363 GWh of waste heat was delivered which displaces 37,800 m<sup>3</sup> fuel oil and 101,700 tons CO<sub>2e</sub> if the heat would have been produced from fuel oil.

**Heat Output:** ~3800 GWh of heat output per raw material.

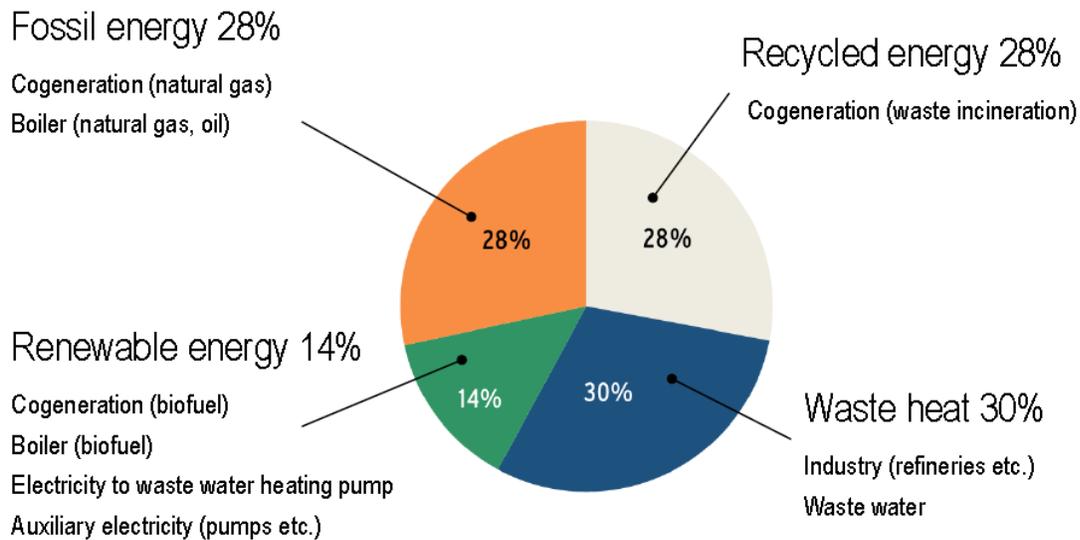
**Energy Supplier:** Shell, Preem (both refineries own the waste heat capture technologies in their plant), municipalities, Göteborg Energi.

**Energy Customers:** residents and businesses in numerous surrounding municipalities.

### **Other Environmental Benefits:**

Residents and businesses in the region who are not part of the district heating system heated their homes with coal in the 1950’s, oil at the end of the 1950’s to 1990’s, and today with electricity and heat pumps.

Fuel mix of district heating system: 30% waste heat (refineries, wastewater), 28% recycled heat (waste incineration), 14% renewable resources (biomass and waste water heat from heat pump), and only 28% fossil fuel-based resources (natural gas cogeneration, and natural gas and oil boiler).



Source 1 (Göteborg Energi, 2009)

### Key Barriers Overcome

- Lack of information;
- Cultural norms;
- Lack of access to capital;
- Environmental externalities; and
- Cost.

### Opportunities and Drivers Identified

The story of Göteborg Energi highlights the evolution of a district heating system. Key drivers incited the introduction of innovative technologies and clean energy over time, allowing the project to overcome multiple barriers. Opportunities and drivers include:

- **Infrastructure and knowledge was established before other conventional energy opportunities were available.**
  - At the end of the 18<sup>th</sup> century, the community of Göteborg built and owned a natural gas distribution system. They became familiar with owning distribution infrastructure, therefore invested in electricity distribution. By the 1950's when district heating was adopted, the company was already involved in the energy business, therefore had much of the knowledge required.

- **Local needs acted as drivers for the inception of district heating.**
  - The community of Göteborg had a need for more electricity capacity. They also had problems with smog whose main sources were: a) chimneys heating homes and b) the coal electricity plant in the centre of town. Hence, they upgraded the coal fired power plant with cogeneration and used the waste heat to heat homes and businesses with district.
- **Energy taxes and a carbon tax put a price on environmental externalities.**
  - Since the 1970's oil crisis, Sweden has had high energy taxes on heating fuels (oil, coal, electricity, natural gas) but not on district heating (although the district heating company pays those taxes if they use heating fuels but not on the waste heat produced). A carbon tax was introduced in 1991 and modified in 1993. The carbon tax provided additional financial incentive to seek heat sources that do not produce additional GHG emissions. Biomass became economical to use because of the tax regime on fossil fuels. These drivers allowed more elements of the project to be cost effective.
- **Government financing helped overcome capital constraints on infrastructure.**
  - In the 1970, government financed a large part of the investment required to connect the waste heat from the Shell refinery to the district heating system. Government used a promise of 30-50% of the financing to speed along negotiations between contracting parties. There was also government investment in the connecting the waste heat from the Preem refinery but not as high – 10-15%. This driver allowed more elements of this project to be cost effective.
- **Favourable energy pricing allowed technology to become cost effective.**
  - The heat pump recovering heat from treated waste water was introduced because of very low electricity prices. The prices were a result of excess electricity from Sweden's newly built nuclear power plant.
- **Densified community in close proximity to some waste heat sources.**
  - Göteborg is a densified community, with multi-use buildings, and much of the housing is multifamily. The original cogeneration facility was located in the heart of the community. The refineries and the heat pumps are all located in the city area. Large buildings located close to one another can keep district heating infrastructure costs lower. Multiuse buildings often allow a better match between energy demand and energy production (if waste heat is available 24 hours a day for most days of the year). Sprawl makes district heating more expensive.
- **Distance can be a cost challenge but it depends on the amount of demand.**
  - It is possible to move heat a long distance. Göteborg is talking about connecting communities 60-70 km north of the oil refineries – it is only a question of the investment and the economics.

- **Risk mitigation through owning cogeneration.**
  - Göteborg Energi has the benefit of having an older heating plant that can now provide peak heating requirements and act as a back-up in the short term. A long term risk mitigation strategy is owning land in strategic areas so they could build more cogeneration if one of the refineries were to leave.

### 12.1.2 PROPOSED WASTE HEAT RECOVERY/DISTRICT HEATING PROJECT AT THE PORT OF ANTWERP, BELGIUM

#### Key Energy Mapping Interests:

An industrial area with similarities to the Alberta Industrial Heartland region has completed an energy mapping exercise and is attempting to pursue an industrial waste heat recovery project to be used to connect to a proposed district heating system in the neighbouring municipality. We are interested in the barriers they are facing to project initiation and how they are overcoming those barriers.

**Location:** Port of Antwerp, Belgium.

**In-service dates:** Energy mapping completed 2010, but, at the time of writing, no project has yet been approved.

#### Technology Description (and timeline):

- 2010 - Heat mapping completed in the Port of Antwerp area approximately 150 km<sup>2</sup>. It found an abundant supply of low temperature heat (from the chemical and refining industry in the area that use high temperature heat and release low temperature heat). Within the industrial site, they found a low demand for low temperature heat with an imbalance of about 40 to one. The solution proposed was to find a use for the heat off-site.
- 2012 - A feasibility study (MIP2 – development of industrial waste heat) determined there was a poor business case for: a) waste heat reuse in greenhouses (there would be too few buildings that would be too small and too far apart for sufficient demand to make waste heat recovery economical), b) on-site organic Rankine cycle (the electricity yield would be too low at the waste heat temperatures available), and c) demineralized water (uncompetitive compared to other technologies available for the process). Waste heat supply to neighbouring low-temperature industrial processes was feasible but the demand is very low compared to the available heat. District heating was shown to be economically feasible if a substantial district heating market is available prior to large investments in large scale industrial heat recovery and transmission.
- 2013 – Another pre-feasibility study (MIP3 district heating) concluded that a start-up phase is required with temporary local heat sources to build the local market for district heating before industrial waste heat is captured and brought to the city. The sooner the waste heat becomes available the more economically feasible the district heating scheme is. A large scale heat network is needed to pay for the transmission line connecting industrial waste heat to the city.

**Power Output:** 1000 MW of waste heat being cooled away at temperatures of 80°C and higher within chemical and refining processes.

**Energy Supplier:** Proposed energy suppliers – various industrial entities.

**Energy Customers:** Proposed energy customer – the nearby City of Antwerp.

**Other Environmental Benefits:** None yet achieved but if the project goes ahead there will be fewer GHG emissions and other air pollutants by using waste heat to heat residential and commercial buildings, and greater efficiencies achieved with a district heating system.

### **Key Barriers:**

The project is currently facing or has overcome the following barriers:

1. Lack of information;
2. Environmental externalities;
3. Costs;
4. Competing priorities; and
5. Cultural norms/inertia.

\* Unless otherwise indicated the source for this case study came from a briefing note and an interview provided by Paul De Rache, Manager of Energy Projects, Port of Antwerp.

### **Barriers and Drivers Identified**

- **A project champion initiated and advanced the project addressing a barrier around lack of information.**
  - Two important factors allowed initiation of this project: 1) Paul De Rache, Manager of Energy Projects, from the Antwerp Port Authority acted as the project champion, and 2) the Port Authority saw that it was within its mandate to allow involvement in the heat mapping and project development.
  - It began in 2007 when Mr. De Rache was driving through the port in the winter and saw all the condensation clouds from the heat being emitted from industry in the Port. He wondered if the Port could do something with all of the heat loss. There is a sizable waste heat recovery market in Belgium although he wasn't aware of that at the time. He was one of the authors of the climate policy statement for the Port of Antwerp so he was thinking about how the Port could reduce their GHG emissions. He had to convince management that an industrial waste heat reuse project is in their best interest and the Port Authority<sup>27</sup> provided a budget to conduct a heat mapping (or energy mapping) study and eventually an economic feasibility study. The studies helped overcome the barrier around lack of information as they provided a path forward on an economic opportunity to reuse the waste heat.
- **Developing district heating market and infrastructure before capturing industrial waste heat will create greater certainty for industry.**

---

<sup>27</sup> The Antwerp Port Authority was established as an independent, municipally-owned company to boost the competitiveness of the Port of Antwerp.

- The economic feasibility of industrial waste heat capture and use proved sensitive to a number of parameters, such as interest rates, and required return on investment for equity. This made it difficult to justify developing industrial waste heat recovery for the purposes of district heating without a well-developed district heating market. Thus, the aim is to first develop a district heating network in Antwerp and subsequently tie-in industrial waste heat.
- **Municipal support and participation may be required for project success.**
  - Support from the City of Antwerp may also help district heating and industrial waste heat recovery become a reality. The Port Authority and the City of Antwerp collaborated in completing the feasibility study for district heating. The study found that the district heating market must first be established (with temporary local heat sources that can eventually act as back-up) in order to justify the investment in the industrial waste heat recovery and transmission. With this knowledge, next steps rely on the City investing in a district heating system. Some commitment from the industrial partners may be required as the sooner you integrate industrial waste heat the sooner the district heating system becomes economically feasible.
- **Public utility development of the project may overcome financial barriers.**
  - The project will have a long payback period and the large upfront capital investment must have a long depreciation period in order to keep consumer prices competitive with conventional heating fuel sources. Thus, the project will likely only proceed if it is developed as a public utility, as they are willing to accept these conditions.
- **Generating broad support for waste heat projects may help overcome barriers and ensure success.**
  - The Port Authority has been actively lobbying the Flemish government to build support for industrial waste heat reuse projects and have already received government financial support. The feasibility study on the industrial waste heat reuse was partially funded by the Flemish government's Environment & Energy Technology Innovation Platform.
  - When the project began, Mr. De Rache helped to establish a Flemish waste heat organization. The organization lobbied in Belgium and the European Commission, during the development of the energy efficiency directive, for increased recognition and support for industrial waste heat projects. At the time of writing, the Flemish waste heat organization were negotiating a multi-stakeholder regional waste heat charter between the City, Port Authority, provincial government, a number of major potential district heat users (e.g. social housing co-ops), public utilities, as well as federations of different industries. The charter is a formal commitment to work together in a long term strategy to transform urban energy supply using industrial waste heat.

- These efforts to generate political and organizational support may help overcome industry's reluctance to pursue waste heat energy projects in Antwerp. Generating broad societal support and momentum for the project could change industry's perception by creating a moral imperative and social pressure for them to pursue the project. It may help industry overcome barriers such as cultural norms/inertia, perceived risk, and/or competing priorities by making it a regional priority.
- **Insufficient financial drivers for industry to reuse waste heat is preventing their active participation.**
  - Industry in the Port of Antwerp has shown little interest in supplying their waste heat to a district heating system, as there are currently insufficient financial incentives for them to do so. Belgium has no carbon tax and the European Union Emissions Trading System has experienced a low carbon price in the last eight years providing almost no incentive for industry to reduce emissions. Without sufficient financial incentive, industry's focus is on their core business not on waste heat capture. Waste heat is not illegal and it does not cost them anything to release into the atmosphere. Some industries are operating in volatile global markets with some difficulty to predict the long term future of their site. Under these conditions, they do not want to make contractual obligations to provide waste heat to outside parties.
- **Newly introduced policies may help overcome information to industrial waste heat reuse.**
  - In December 2013, the Flemish Regional Parliament adopted a resolution in which it urges the Flemish Government to develop and implement a Flemish Heat Policy. There was broad acceptance for the resolution as parties on the left support it as a sustainability policy, and parties on the right view it as a strategy for energy-independence and job creation.
  - The EU's Energy Efficiency Directive 2012/27/EU is the first framework that addresses the recovery of industrial waste heat. The Directive was designed to ensure the achievement of the EU's target to achieve a reduction of 20% from 1990 GHG levels. By 2016, member states are required to provide a comprehensive assessment of the potential for high efficiency cogeneration, efficient district heating and cooling, and the use of heating and cooling from waste heat and renewable energy sources based on a country-wide cost-benefit. States are then required to take adequate measures to develop or accommodate the development of these projects, where the comprehensive assessment identifies a potential whose benefits exceed the costs.
  - Policies are to be adopted at the local and regional levels to encourage efficient heating and cooling systems. Authorization or permit criteria and procedures for operators of electricity generation installations, industrial installations and district heating and cooling installations are to be adopted, so they carry out installation-level cost-benefit analysis on the use of high-efficiency cogeneration and/or utilization of waste heat and/or connection to a district heating and cooling network. These permit criteria and procedures are required if planning to build or refurbish capacities above 20 MW thermal input or when planning a new district heating and cooling network.

- **Simple policy change removed one cost barrier to district heating.**
  - Previously, building developers were legally required build infrastructure connecting all new residential units to the natural gas grid. Heat distribution infrastructure would represent an additional infrastructure cost, thereby reducing the cost effectiveness of district heating projects. This policy was helping maintain monopoly of the natural gas heating industry and presenting an additional cost to district heating systems which indirectly also acted as a barrier to waste heat reuse projects (by decreasing the economic viability of district heating there is fewer demand opportunities for industrial heat reuse). Under the new law, introduced in 2013, they can choose to install gas or heat infrastructure.
- **Population density and city owned housing helps makes the business case for district heating.**
  - The City of Antwerp is densely populated which improves the economic viability of a district heating system. A key revenue parameter is the number of kilowatts of heat they sell per kilometer of piping. Another factor that improves the business case for the project is that a good percentage of the service area is city-owned low income housing. Therefore, a significant amount of demand could be secured through one single contract greatly simplifying the contract process.

### 12.1.3 INDUSTRIAL COGENERATION PROJECTS IN SARNIA-LAMBTON, ONTARIO

**Key Energy Mapping Interests:** Multiple industrial companies came together in two different waste heat energy generation projects (co-generation) to improve their competitiveness eventually leading to the development of an energy industrial park that is attracting tenants with their low electricity rates. The vision for the projects was to create a unique Sarnia-Lambton Energy Advantage - to use regional cogeneration to attract investment and allow industry, already in the area, to remain competitive through lower power rates.

**Location:** Sarnia, Ontario.

**In-service dates:** Energy Joint Venture 1995, Sarnia Regional Cogeneration facility 2003, Bluewater Energy Park created in 2010.

#### **Technology Description (and timeline):**

- 1995 – An Energy Joint Venture (EJV) became operational between NOVA Chemicals (Canada), Dow Chemical Canada Inc., and the Rubber Division of Bayer Rubber Inc. by joining the gas fired turbines at Dow Chemicals and oil fired turbines at Bayer Rubber to produce electricity and steam for on-site use. The surplus steam was supplied to the Novacor Chemicals Sarnia polystyrene unit. Electricity not directly used by Bayer or Dow was sold to Ontario Hydro and fed to the grid. In service generation capacity was 120 MW at Dow and 30 MW at Bayer. The project was managed by an Executive Board consisting of representatives from each of the three participating companies

- 1997 – The concept of a Sarnia regional cogeneration facility was initiated. There were plans for 523 MW of electricity and 1.6 million pounds of steam per hour to be sold to seven industrial clients
- 2002 – EJV assets purchased by TransAlta.
- 2003 – Commercial operation of Sarnia Regional Cogeneration Plant begins. The plant is a 575 MW gas-fired cogeneration plant (440 MW new gas-fired facility integrated with 135 MW from the EJV). This was Ontario’s first new power generation built by a private sector investor. TransAlta contracted up to approximately 216 MW of capacity to Bayer, Dow, NOVA Chemicals, and Suncor Energy Products Inc. An additional 75 MW was contracted over the next three years. The remaining capacity was to be sold through bilateral contracts or into regional wholesale markets. In addition, all steam was sold under 20-year contracts to Bayer, Dow, NOVA and Suncor.
- 2006 – Dow announces closure of all manufacturing in Sarnia due to interruption of the supply of a critical feedstock, ethylene.
- 2009 – Sale of the majority of the Dow Sarnia site property to TransAlta Corporation.
- 2010 – Bluewater Energy Park opens on the former Dow property and announces its ability to provide “behind-the-fence” rates to its tenants through the Sarnia Regional Cogeneration Plant.
- 2012 – Solutions4CO2 Inc. established its Global Operations and Research in the Bluewater Energy Park.
- 2013 - Ubiquity Solar Inc. announces plans to set up an \$11 million pilot plant in the Bluewater Energy Park.

**Power Output:** 150 MW 1995, 575 MW 2003.

**Energy Supplier:** Initially Dow and Lanxess (formerly Bayer Rubber Inc.), and eventually TransAlta.

**Energy Customers:** Dow, Lanxess (formerly Bayer Rubber Inc.), Suncor, NOVA Chemicals, Solutions4CO2, and soon Ubiquity Solar Inc.

**Other Environmental Benefits:** Fewer GHG emissions and other air pollutants from more efficient power generation.

### **Key Barriers Overcome**

- Coordination complexity;
- Transaction costs; and
- Search Costs.

### **Barriers and Drivers Identified**

- **Increases in electricity prices created a need to look to alternatives.**

- Provincial electricity prices was one of the key drivers the Energy Joint Venture (EJV) (Nisbet, 1998), Sarnia Regional Cogeneration Plan, and the Bluewater Energy Park. In the early 1990s, Ontario Hydro had three consecutive years of double digit rate increases. This was affecting the competitiveness of the local petrochemical and refining complex. The Ontario Petrochemical Task Force found electricity costs are not competitive with competing jurisdictions in Alberta and U.S. Gulf Coast. Essentially, cost became a key driver to seek generation alternatives and was significant enough to overcome barriers facing the projects.
- **Cogeneration technology was already well established but the coordination of numerous companies was a unique characteristic of this case study.**
  - Prior to the project, cogeneration was already a well- established technology. It is the coordination between industrial companies that is a relevant best practice to highlight in this case study. First cooperation in the EJV between three companies allowed utilization of spare generating capacity and lower electricity costs. The EJV then expanded to include more companies and more generating capacity to help address the problem of high energy prices. Thus, it is the coordination seen between companies (enabled by the local economic development organization) not the application of an innovative technology that is unique and desirable in this case study.
- **Local economic development organization acted as a catalyst for the project, which helped overcome typical project barriers.**
  - The Sarnia-Lambton Economic Partnership (SLEP) played a key role in helping the cogeneration projects overcome barriers that may have prevented them from moving forward. SLEP is a private/public sector community-based partnership that works to continually increase the economic activity in the City of Sarnia and the County of Lambton. As Ontario electricity prices increased throughout the 90's, SLEP wanted to explore whether they could create a unique Sarnia-Lambton Energy Advantage. Could they enable regional lower cost electricity generation to act as an investment attraction tool? SLEP's first step was to initiate meetings about an Energy Joint Venture between three companies.
  - After the EJV became a reality, SLEP wanted to expand the capacity of regional cogeneration. Research and discussions indicated that a larger cogeneration project might be possible. SLEP organized a meeting inviting all major power users to discuss potential for the project to determine if it was worth pursuing and if so to determine a path forward. The over thirty attendees from all major industries asked SLEP, given their neutral role, to become secretary/administrator for the group. Ultimately, a request for proposal was created, issued, and administrated by SLEP which selected TransAlta as the developer.
  - Electricity prices rose across Ontario but co-generation projects with multiple industry players were not the norm in Ontario at the time, therefore one might ask what was unique about the Sarnia Lambton region that enabled the project that required coordination of multiple companies to proceed? One answer would be the coordination efforts of SLEP. This paper previously discusses that often unseen costs exist that act as barriers to waste heat projects such as: the coordination complexity of projects with multiple industrial partners, transaction or time and administrative costs of managing numerous organizations, and search costs for finding the appropriate information about costs, technology, enabling policies and permitting procedures. SLEP's efforts would

have absorbed or buffered some of these costs for industry members involved in the Sarnia cogeneration projects.

- **Timely research also acted as a catalyst for Sarnia regional cogeneration project.**
  - A paper on case studies of industrial partnerships in the Sarnia-Lambton area (which highlighted the EJV) concluded that further opportunity exists for sharing and cascading of excess steam and heat. SLEP had initial discussions with knowledgeable industry members who also thought a Sarnia Regional Cogeneration Plant was a feasible way to lower industrial electricity costs. The research and input from industry gave SLEP the confidence to pursue the Sarnia regional cogeneration project.
  
- **Changes in provincial electricity policy enabled the projects.**
  - Proposed changes in provincial electricity policy was another key driver that helped to initiate the Sarnia regional cogeneration project. All of the projects required policy changes in order to allow the sale of electricity between industry members regionally and to allow TransAlta's behind-the-fence pricing in the Bluewater Energy Park.
  - November 1997, the Ontario Ministry of Energy (Science, and Technology) released a "White Paper" that outlined a plan for introducing full competition into the provincial electricity system by 2000. The paper proposed that, "private power companies and industrial co-generators would have open access to transmission and distribution. This would provide investors with the confidence to commit to new generation projects whenever they see viable investment opportunities." This policy indicator provided the project with the confidence to begin to move forward.
  - While there was limited follow-through on the policies changes outlined in the White Paper (see further discussion below), the initial ambitious policy created the momentum to initiate the Sarnia regional cogeneration project.
  
- **Provincial electricity policy created barriers throughout the history of the three projects.**
  - While policy change was a driver for these projects, the slow pace of policy change and lack of follow-through on some assurances acted as a significant barrier to the projects. The increased energy prices acted as a significant enough driver to overcome these bureaucratic barriers.
  - The Sarnia regional cogeneration project began under the pretense that there would be full competition in electricity generation by 2000. The original concept was to attract energy intensive industry in to the region and maintain the competitiveness of existing industry with the lower electricity prices. As Ontario electricity policy came to fruition, it became more apparent it was not going to allow certain relationships and fewer companies were able to participate in the cogeneration project. For example, the project was not able to service companies in the St. Clair township as they could not use the transmission system to transport the electricity to industry in the area – regulation did not allow them to use the existing grid to transport electricity nor would it allow them to build a separate transmission line.
  - TransAlta was the first private sector investor to build new power generation in Ontario. Given the lack of clarity over a three year period on provincial electricity policy, and the significant effort it required to enable the policy changes that would allow the project to move forward, TransAlta had to take a significant leap of faith to commit to the project.

- **Negotiations and a supportive member of parliament allowed incremental policy changes that enabled each project.**
  - All three projects required intensive lobbying of the provincial government and subsequently negotiate policy changes or exceptions to policy with Ontario Hydro. Support from the local Member of Parliament also helped to overcome bureaucratic barriers that were hindering the projects.
  
- **Behind-the-fence energy pricing is now being used to attract clients to Bluewater Energy Park.**
  - Case studies of industrial partnerships in the Sarnia-Lambton area found that several factors made the area well-suited to the development and successful operation of a major eco-park modeled on the Bruce Energy Centre with one or two major companies supply energy to smaller companies. These factors included: in-place industrial infrastructure, skilled labour force, abundant sources of by-product energy, available space, proximity to major markets in Canada and the U.S., vacuum left from downsizing or departure of industrial operations, need to maintain critical industrial mass in the corridor, and the need to maintain a competitive position with similar petrochemical complexes in North America. This paper was written in 1998, and the concept became a reality in 2010 through the Bluewater Energy Park. Delays were due to policy barriers created from regulation allowing limited competition in the electricity sector.
  - When Dow shutdown the majority of its manufacturing in Sarnia (due to a lost supply of its critical feedstock, ethylene), the reduction in demand and the availability of the Dow property, allowed the concept of an eco-industrial energy park in Sarnia to be realized. Bluewater Energy Park now offers tenants steam at three different temperature/pressure levels and "behind-the-fence" lower priced electricity. Lower energy prices are possible in siting tenants close to the Sarnia Regional cogeneration Plant in the Bluewater Energy Park as it avoids transmission and overhead costs typically charged when taking power from the Ontario power grid. The average industrial price for electricity in Ontario is about \$0.11/kWh whereas the Bluewater Energy Park can offer about \$0.06/kWh. TransAlta's Sarnia Regional Cogeneration Plant still continues its long term contracts to supply steam and electricity with three of the four original project participants - LANXESS, NOVA and Suncor Energy.
  - The concept behind the Bluewater Energy Park is what SLEP envisioned back in 1997. Bluewater Energy Park is using lower than average electricity prices to attract new industry to the area. To date, two new tenants have been attracted to the Bluewater Energy Park. Solutions4CO2 Inc., a company that designs, builds, operates and maintains industrial solutions to capture waste gas and water streams and process them into value added co-products, established its Global Operations and Research in the Bluewater Energy Park in 2012. Ubiquity Solar Inc. has plans to set up an \$11 million pilot plant in the Bluewater Energy Park.
  
- **Projects took advantage of existing infrastructure to save on costs.**
  - Each project took advantage of existing infrastructure to save costs. The Energy Joint Venture was realized when Dow shut down its chlorine unit therefore had excess generating capacity. Bayer had a cogeneration unit but had downsized its production and therefore also had spare generating capacity. The infrastructure for the EJV was mainly in place with the exception of the steam line to Novacor Chemicals. The Sarnia Regional Cogeneration Plant was built along a major pipeline corridor and there was already a

major steam line in place. The Bluewater Energy Park took advantage of the available Dow infrastructure and land.

#### **12.1.4 SHELL SCOTFORD MANUFACTURING IN ALBERTA'S INDUSTRIAL HEARTLAND**

##### **Key Energy Mapping Interests:**

Examining the drivers behind a good practice example in Alberta around waste heat re-use and energy efficiency.

**Location:** Edmonton, Alberta

**In-service dates:** 1984

Unless otherwise indicated the source for this case study came from an interview provided by Michelle Kalita-Onushko, Process Engineer, Jessie Smith, Process Engineer-in-Training, and Conal MacMillan, Communications and Social Performance Advisor.

##### **Technology Description (and timeline):**

- 1984: the Shell Scotford Refinery and Chemical plant (styrene monomer unit) begins operation
- 2000: monoethylene glycol (MEG) unit addition to the Chemical plant begins operation. This addition was designed to be integrated with existing plants
- 2003: the Shell Scotford Upgrader begins operation
- 2011: expansion to the Upgrader is initiated. Like the MEG plant, integration was a key design consideration
- 2012: Quest carbon sequestration project is announced and is projected to begin operation in 2015

## Plant description:

Shell Scotford is four plants in one: an upgrader, a refinery, cogen and steam generation plant, and a chemicals plant. The Upgrader is designed to process bitumen from the Shell Albian Sands mine into synthetic crude oil (SCO) by adding hydrogen and removing impurities like sulphur. The refinery takes SCO from the Upgrader and other suppliers and produces different types of fuels such as diesel, gasoline, jet fuel and propane. The Chemicals plant produces styrene monomer from benzene (a by-product of refining) and ethylene feedstocks. MEG is produced in the glycol unit of the Chemicals plant using oxygen and ethylene feedstocks.

In terms of electricity generation, Shell owns and operates an 18 MW steam turbine on site. There is also an ATCO cogeneration plant on site that has an 84 MW gas turbine and 95 MW steam turbine (using steam produced from the exhaust of the gas turbine).

There is an Air Liquide plant adjacent to the Shell Scotford plant. They operate a cogeneration plant (gas turbine), and they send electricity, oxygen as a feedstock, utility nitrogen and steam to the Shell Chemicals plant. It also provides utility nitrogen to the Shell Upgrader. Air Liquide recovers and purifies a portion of CO<sub>2</sub> from Shell's glycol operations for use in enhanced oil recovery and for non-industrial uses.

Air Products is building a plant near the Shell Scotford plant to supply hydrogen for the upgrader and refinery. The steam generated in the hydrogen production process will be used by the Shell Scotford complex processes.

Aux Sable takes refinery off-gas streams and recovers natural gas liquids, ethane, and hydrogen and the hydrogen is transferred back to Shell Scotford for use in the refining process.

Operational in 2015, the Quest Carbon Capture and Storage (CCS) project will capture more than one megatonne of CO<sub>2</sub> per year, or 35% of Shell's Scotford Upgrader GHG emissions per year. The CO<sub>2</sub> will be purified and compressed at the Scotford facility and then be transported by pipeline up to 80 kilometers north of the facility to underground injection wells to be pumped into deep geological formations to store the CO<sub>2</sub>.

**Other Environmental Benefits:** The integrated nature of the Shell Scotford complex and its waste heat reuse results in less GHG emissions and other air pollutants than from a comparably sized standalone facility.

## Key Barriers Overcome

Competing Priorities

Costs

## Barriers and Drivers Identified

- **Integration of plants allows for substantial energy efficiency gains/waste heat re-use opportunities.**
  - The integration of the refinery, upgrader, and chemical plant (along with the additional Chemical and Upgrader units added over time) is one factor allowing the Shell Scotford complex to be one of the most energy efficient facilities of its kind. When plants are integrated, they share utility systems (steam, fuel gas, natural gas and electricity), water, feedstocks, and/or product streams. Integration provides operators with flexibility in how they operate the plant, which can increase the efficiency of production. Operators at the Shell Scotford plant can move steam and fuel gas around the site and optimize their use and generation.
  - This flexibility not only allows increased efficiency but it enables increased reliability allowing production to continue uninterrupted during planned and unplanned equipment outages. This ensures the complex can operate to its greatest capacity. For example, operators can choose where steam is produced choosing to run more efficient boilers over lower efficiency boilers. But if operational reliability is at risk, they have the option of bringing a less efficient boiler online to help other areas of the complex if there is a need for more steam generation. A good analogy for this flexibility in using and producing energy in different areas of the integrated plant would be a traffic circle. Traffic can enter and exit at various points of a traffic circle depending on need as determined by traffic flows at different times of the day. At the Scotford Shell facility, steam goes to an integrated steam header, which can direct it back and forth between systems depending on production needs, and efficiency optimization.
  - Integration of the plants also allows for energy cascading more readily between processes or different energy end-uses. Energy cascading occurs where high grade heat is used in a process, the resulting heat is of a lower grade (or temperature), but can still be used again as long as there are processes that require medium grade heat, and subsequently lower grade heat in processes down the line. In other words, high pressure steam is generated and then the pressure and temperature drop as the steam is cascaded through different processes. For example, heat from steam boilers can be put through turbines to run a motor or compressor, the medium grade heat from the turbine exhaust can then be used in a distillation column, and even afterwards the lower temperature heat leaving the distillation column can be used to heat a tank to maintain lower viscosity of materials in winter operations, or even for heating of buildings. In general the higher the temperature and pressure of a heat source, the more value it has since it can be used in a greater variety of industrial processes. The Shell Scotford facility has multiple steam levels depending on the pressure, temperature and contamination level of the steam.

- Integration with other companies has also allowed for energy cascading between companies. The ATCO Electric and Air Liquide cogeneration plants, on and just outside of the Shell Scotford site, respectively, very efficiently produce steam and electricity that are used by the Shell Scotford plant and the energy is cascaded after its initial use. The primary purpose of these cogeneration plants is to provide electricity to site but there is the capability to feed any surplus electricity to the grid.
- **Designing for efficiency/waste heat re-use, as well as being a new facility allowed for greater efficiency.**
  - The Scotford Upgrader and Refinery are ranked in the top quartile in terms of energy performance by Solomon's Energy Intensity Index<sup>28</sup> when compared to upgraders and refineries of similar technical complexity worldwide. Two major factors enabled energy efficiency at the Shell Scotford facilities: 1) it is a "new" facility (as compared to the same types of facilities elsewhere), and 2) there was a key focus on energy efficiency and integration in its design. One of the many advantages of being a large global company is much of the learning around energy efficiency/waste re-use from other operating Shell facilities was taken into account in the design of the Shell Scotford facility. Many of the efficiency considerations embedded into the design of each plant would not be viable in a retrofit situation. Retrofitting for energy efficiency is most often more expensive than simply including the upgrades in the original design.
- **Shell's culture allows for energy efficiency to be considered alongside production projects.**
  - Shell uses energy efficiency as a performance metric alongside more traditional performance indicators like "production". Shell has a global policy to allow for a lower return on investment (ROI) threshold value for energy efficiency projects as compared to other capital projects. This can help energy efficiency projects gain an edge when competing for capital with other potential investments. Given a number of factors are taken into consideration when evaluating various capital investments, staff also consider how energy efficiency projects may enhance reliability and provide additional benefits to build the case for these projects.
  - Shell is weaving the ideas of lowering energy consumption and air/water emissions into the organization, including at upper management levels. Energy efficiency metrics are tracked and reported world-wide. The Shell upper management team examines energy efficiency performance world-wide; they take a look at the big picture and pick and support strategies that work well for Shell. This focus creates an atmosphere where the organization continuously strives to maintain and improve excellent energy efficiency in operating facilities.

---

<sup>28</sup> <http://s04.static-shell.com/content/dam/shell-new/local/country/can/downloads/pdf/oil-sands/oil-sands-performance-report-2012.pdf>

- **Cost is still a major driver for all projects.**
  - Cost is still a major consideration of all energy efficiency projects. An initiative has to make business sense in order to be approved. Staff complete cost benefit analysis for all of their energy efficiency/waste heat energy projects.
  
- **Integration was pursued not only for energy efficiency but also to increase production reliability.**
  - While there is often already energy savings and thus cost saving advantage of energy efficiency through integrated industrial facilities, operational staff at Shell also see system reliability as the key driver to pursuing these projects. The reason is reliability and energy efficiency are seen as interrelated. Energy efficiency is seen as tied to greater operational equipment reliability, which is tied to more production, and collectively they make excellent business sense.
  
  - Plant reliability is the first matter of consideration because it is tied to safety, environmental impact, and production, and also because it can have a great impact on energy consumption. If one unit is shut down, it will use more energy to get it back up and running than if the plant kept running at steady state. Basically, plant shut-downs cost energy. Therefore, some decisions are based on what's best for the entire facility not necessarily the greatest efficiency.
  
- **The operations staff at the Shell Scotford site maintain a culture of efficiency.**
  - Operations staff at the Shell-Scotford site do not see heat energy coming out of a process as “waste heat”, they simply see it as a lower grade of heat or energy, and try to find a useful application for the energy. Staff try to use every bit of energy before they have to (perhaps) call it “waste”.
  
- **Staff efficiency training demonstrates energy efficiency/waste heat re-use is a priority for Shell.**
  - Shell also has energy efficiency training in place for operators. Shell has their own training department, and all operators have to pass accreditation to work in the production units. Shell Scotford is currently implementing a Carbon and Energy Management Information System (CEMIS) as a global Shell standard for monitoring energy efficiency. CEMIS is a visual tool that identifies key energy using processes in each unit, looks at historic performance, and in real time it tells operators how the equipment is operating relative to the best historical energy performance. This system can provide suggestions to operate more efficiently. Best performance is determined by industry best practice and from consultation with operators on site and with technical staff.

- **Further waste heat reuse will occur through the Quest CCS project. The project also demonstrates Shell’s further willingness to pursue innovative environmental projects.**
  - Low pressure steam from the Shell Scotford site will be used in the compressors transporting CO<sub>2</sub> to the Quest site. Minimal low pressure steam will have to be generated; rather it will first be reallocated from existing lower use applications within the facility. Quest will be the first CCS project for an oil sands operation in Canada. As Shell’s Executive Vice President of Heavy Oil, John Abbott stated, “The project’s technical and strategic value reaches beyond the emissions it will capture. Quest is important because it is a fully integrated project that will demonstrate existing capture, transportation, injection and storage technologies working together for the safe and permanent storage of CO<sub>2</sub>. The knowledge it provides will help to enable much wider and more cost-effective application of CCS through the energy industry and other sectors in years to come” (Shell Canada, 2012). Like their energy efficiency and waste heat re-use achievements at the Shell Scotford facility, this project further exemplifies Shell’s commitment to innovative environmental projects.

# 13 APPENDIX: REVIEW OF HEAT CAPTURE TECHNOLOGIES

---

Waste heat results from thermodynamic limitations on industrial processes, from equipment inefficiencies and from practical limitations on heat transfer. In fact, these inefficiencies and thermodynamic limitations also impose practical constraints on the utilization of the waste heat.

Waste heat is generally classified as low grade, medium grade and high grade based on the temperature of the hot fluid or gas carrying that heat. Although these temperature ranges are not defined rigidly, the generally acceptable ranges for waste heat are: low grade below 200 °C, medium grade between 200 and 600 °C and high grade above 600 °C. Waste heat recovery opportunities can be understood from the perspective of the recovery equipment or the recovery method.

Three broad methods are employed for utilizing waste heat. Waste heat could be recycled within the heating system, recovered using a recovery or auxiliary system, or converted to electrical power. The application of each of these methods is dependent on the quality of waste heat, process conditions, nature of the application, and economics.

Waste heat recycling methods include preheating combustion air, load or charge; and internal heat recycling (heat cascading). Waste heat recovery using auxiliary methods include the use of heat for steam generation, water heating, space heating, absorption cooling systems, and process heat requirements. Heat-to-power generation methods include 'conventional plants' using steam turbines and generators or Organic Rankine Cycle, Kalina and Neogen (ammonia-water systems), and thermo-electric power generation systems.

Recovered heat may be useful on an industrial site itself, or there may be synergies between neighbouring plants where heat could be sold as a utility across fence lines. The following sections describes some technologies for which can capture or utilize waste heat.

## 13.1 RANKINE CYCLE (STEAM TURBINE)

The Rankine cycle is one of the most common thermodynamic power cycles, and generally uses water as the working fluid. If waste heat from industrial processes is at a high enough temperature, steam can be generated and passed through a turbine to generate electricity. Due to the high temperatures involved, a steam power plant can be quite efficient. However, this type of power plant requires many skilled operators, which means that only large projects typically make economic sense. Waste heat streams need to be very high temperature to be used with this technology.

## 13.2 ORGANIC RANKINE CYCLE (ORC)

An ORC machine generates electricity with the same thermodynamic cycle as a Rankine Cycle, but with an organic working fluid (e.g., Toluene, pentane, refrigerants) that has a lower boiling point than water.

ORC machines are generally used where waste heat between 80 °C and 300 °C is available. ORC has cycle efficiencies from 8% to 20% depending on temperature difference between inlet and outlet, with higher temperature drop leading to higher efficiencies. Useful heat can also be recovered from the outlet side with temperatures suitable for space heating or low-temperature process heating when the temperature on the outlet side is sufficiently high.



Figure 15: PureCycle Organic Rankine Cycle generator from Pratt & Whitney

### 13.3 KALINA CYCLE

The Kalina Cycle is similar to the ORC but uses a binary working fluid in a mixed solution. The different fluids have different boiling points, which enables it to be used for electricity generation over a wider range of input temperatures than is possible with ORC. The Kalina cycle operates like a combined-cycle power plant, but with less machinery. Efficiency gains of 10% - 20% are possible over single-fluid ORC.

### Simplified Kalina Cycle™(Exergy,Inc.)

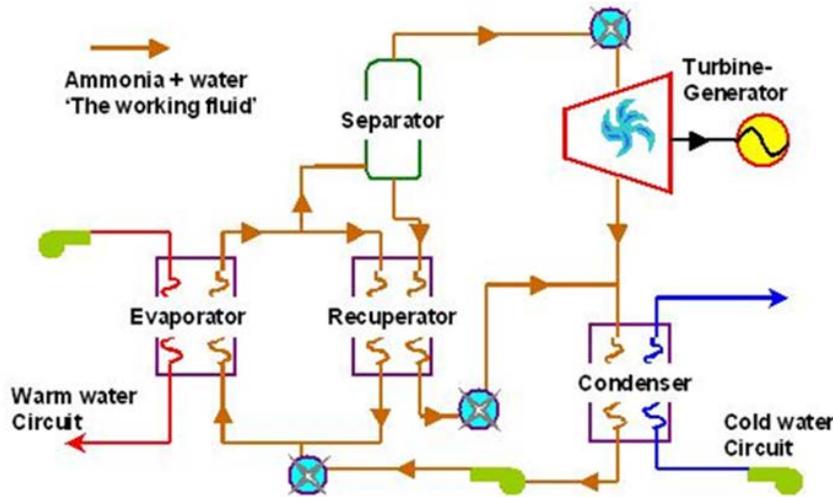


Figure 16: Schematic of Kalina cycle from Exergy, Inc.

## 13.4 STIRLING ENGINES

In a Stirling engine, an enclosed mass of gas is alternately moved from a heated end to a cooled end of a cylinder. When the gas is near the heated end, the gas absorbs heat and expands, thus pushing on a piston. The arrangement of pistons is such that the motion moves the gas away from the hot end and towards the cooled end of the cylinder where the gas loses heat and the volume decreases. The momentum of a flywheel connected to the pistons pushes the gas to the hot end of the cylinder again and the cycle repeats. The engine is almost always used to drive an electricity generator, typically in the range of 100 kW or less. Stirling engines are able to be set up as combined heat and power systems where the heat rejected from the cooling end of the cylinders can be captured and used in other processes such as building or water heating.

The Stirling cycle has a theoretical efficiency equivalent to the Carnot efficiency, which is the theoretical maximum possible for any type of heat engine. However, due to parasitic losses and friction, the actual efficiency of a real Stirling machine is often  $\frac{2}{3}$  to  $\frac{1}{2}$  of that maximum. In a CHP system, the overall efficiency can be as high as 95%.



Figure 17: 7.5 kW free-piston Stirling engine generator from Qnergy

Stirling engines are considered an “external” combustion engine (as opposed to internal combustion) since the heat is applied outside the cylinder where the gases act on the piston. In an internal combustion engine, such as those driving most automobiles, heat is applied within the cylinder through the combustion of a fuel. The advantage of external combustion is that any heat source at a temperature greater than the starting temperature of the engine (generally 80°C) can be used. These heat sources can be from combustion of solid, liquid or gaseous fuels in a burner arrangement, or hot gases from another industrial process, or even a high temperature fluid such as steam or glycol. This adaptability to fuel and heat sources and low maintenance requirements makes Stirling engines an attractive choice for remote sites where waste gas is available (such as oil well-heads) and where servicing is prohibitively expensive. Stirling engines are often very reliable and have very low maintenance requirements.

## 13.5 THERMOELECTRIC

Thermo-electric generators operate based on the Seebeck Effect which allows heat to be converted directly into electricity based on material properties and a temperature difference which causes electric current to flow in a bi-metallic junction.



Figure 18: Gas-fired thermoelectric array from Global Thermoelectric

The device requires high temperatures (~250 °C) and typical efficiencies are 5 – 8%. Thermo-electric generators are mostly used in remote sites where waste gas is available and the cost of extending the electricity grid to the site is prohibitive. The device has the generators surrounding gas burners to produce a high temperature difference; however the effect will work with any high temperature source. Thermo-electric generators have the advantage of no moving parts meaning they are very robust and low maintenance.

## 13.6 NON-CONDENSING & CONDENSING HEAT EXCHANGERS

Non-condensing heat exchangers drop temperature of exhaust gases to temperatures above the condensation temperature of the water vapour in the stream and collects the sensible component of heat energy only. The dew point temperature of the flue gases (when condensation begins) depends on the moisture content of the flue gas.

Condensing heat exchangers drop the temperature of flue gases below the condensation temperature of the flue gases, enabling the recovery of both sensible and latent heat.

Contaminants in the flue gases (such as SO<sub>x</sub>, NO<sub>x</sub>, and CO<sub>2</sub> itself) that may cause the condensate to become acidic, which may lead to corrosion issues with the heat exchanger and the stack. Sometime it is possible to address such issues by using alternative materials or adding chemicals to the condensate to maintain a neutral pH.

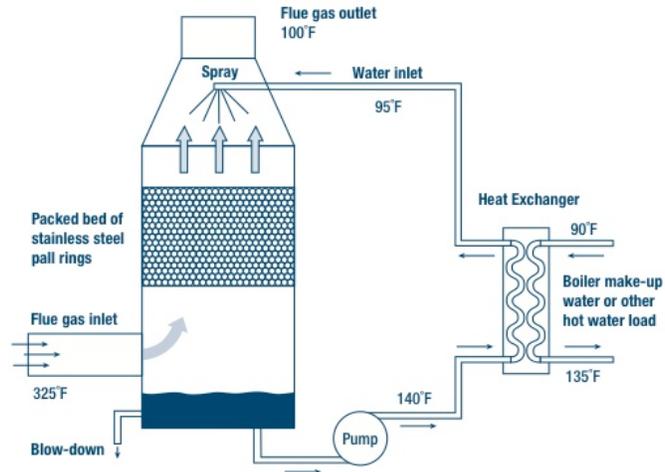


Figure 19: Condensing heat recovery by water spray into flue gases

## 13.7 TRANSPORT MEMBRANE CONDENSER

The Transport Membrane Condenser (TMC) is a relatively new technology, which uses a porous ceramic to collect moisture from flue gases via capillary action. The ceramic is highly resistant to corrosion, and can be made to be highly selective so that only water moves through the ceramic and pollutants remain in the flue gases.

With transport membrane condensers sensible heat, latent heat, and demineralized water can be collected. TMC is an attractive technology where the combustion fuel and consequently the flue gas contains a high percentage of moisture, such as in coal fired boilers or furnaces, and water recovery is a significant issue.

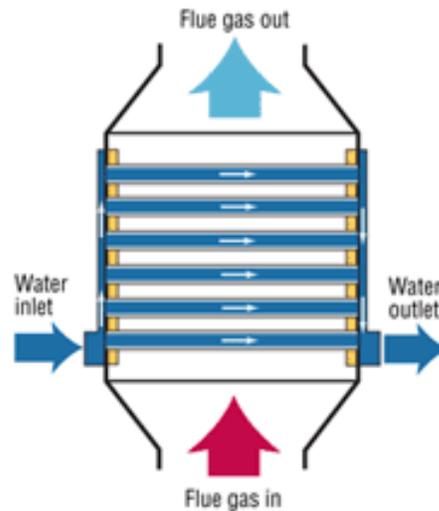


Figure 20: Schematic of water path within a transport membrane condenser, from Cannon Boiler Works, Inc

## 13.8 HEAT PIPES

Heat pipes use sealed pipes containing a refrigerant that absorbs heat at one end and rejects the heat at the other end. When heat is applied, the refrigerant boils and the vapours move to the highest point in the pipe due to buoyancy. A cooling stream is passed over the exterior of the pipe where the vapours collect, which causes the refrigerant to condense back into a liquid and drop to the bottom of the pipe due to gravity. The use of wicking materials within the heat pipe can allow the pipe to operate in orientations other than vertical. The refrigerant cycles automatically based on temperature differences between the two ends of the pipe.

Because the heat pipe depends on convection for the heat transfer mechanism, the effective thermal conductivity is very high compared to using material properties alone. Heat pipes can have effective thermal conductivities up to 100,000 W/m.K

which is very high even compared to copper (a very heat conductive material) which has a thermal conductivity of ~400 W/m.K.



Figure 21: Heat pipe air-to-air heat exchanger recovering heat from exhaust to incoming air, from AMS

## 13.9 TEMPERATURE UPGRADE: HEAT PUMP

Heat Pumps use electricity to drive vapour-compression cycles that take heat from a low temperature source and transfer the heat to a high temperature sink. The coefficient of performance (COP) of heat pumps can be quite high – on the order of 4 or 5 – meaning that for every kW of electrical input, 4 or 5 kW of heat is rejected at the high temperature side of the device.

The newest generation of heat pumps using CO<sub>2</sub> as working fluid can produce hot-side heat up to 130 degrees C with COP of 2.



Figure 22: Unitop® industrial heat pump

## 13.10 TEMPERATURE UPGRADE: STEAM RECOMPRESSION

Low pressure steam can be re-compressed to increase the temperature and pressure of the steam, thus increasing its usefulness. However, given the laws of thermodynamics, this option must be considered carefully since it takes a fair amount of high quality energy to recompress steam. However, there may be processes internal to an industrial site where it may be advantageous to recompress an existing waste steam source.

## 13.11 HEAT TO COOLING

Absorption chillers are counter-intuitive devices that use a heat source to produce a cooling effect. The cycle uses a binary fluid in which heat is added to vaporize one of the components (the refrigerant) out of solution while the other component remains liquid. The refrigerant is directed to a heat exchanger where heat is rejected to atmosphere and the refrigerant condenses as a liquid. The liquid refrigerant is passed through a restriction where the pressure drop causes the liquid to evaporate and absorb heat from an external source. The gaseous refrigerant is absorbed back into the carrier fluid and the cycle begins again.

Absorption chillers can be used on industrial sites for process cooling, or to cool inlet air for air compressors, aerial coolers, or gas turbines thereby increasing the efficiency of these devices.



Absorption chiller flow diagram

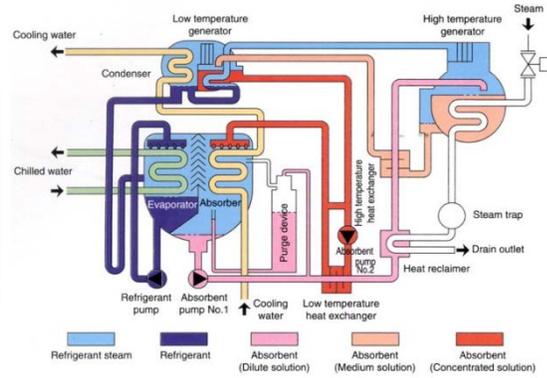


Figure 23: Absorption Chiller from World Energy Absorption Chillers Europe, Ltd.

# 14 APPENDIX: FEEDBACK FROM EXPERT REVIEWERS

---

## 14.1 EXPERT REVIEW PANEL

Alberta is home to many experts and people with direct experience in large industrial facilities. C3 and AITF decided it would be valuable to capitalize on this latent knowledge resource and host a panel of experts to discuss the preliminary results of the study, identify possible uses for this waste heat and provide input into technology that could be considered as part of proposed integrated energy solutions.

The panel was selected from people representing industries who were preferably not related to the current Industrial Heartland energy mapping study. The invitations were met with enthusiasm and the panel ultimately had representation from those in district heating, power generation, large industrial plants, and major oil and gas companies. The seven industry representatives are listed below:

- Neil Camarta
  - CEO and President – Western Hydrogen
- Bob Mitchell
  - Manager, Climate Change, Business Development and Strategic Planning, Conoco Phillips Canada
- Pat Bohan
  - Director, District Energy Generation & Wholesale Energy, ENMAX
- Jim Seaba
  - Manager, Facilities Technology and Integration, Conoco Phillips Canada
- Alan Chambers
  - Alberta Innovates Technology Futures
- Frank Vagi
  - Senior Process Advisor, Bantrel
- Warren Frost
  - Director, Consulting Services, Genalta Power

The panel was asked to provide detailed technical input on engineering and technology issues and solutions. This group provided written assessments, advice through facilitated meetings and review of the final report. The expert panel signed non-disclosure agreements with C3, thus we cannot release the specific content of their discussions. However, there were several general themes that the panel arrived at over the course of the day, which are summarized below:

1. Waste heat is best used within the process first, secondly for generating electricity, then on site for non-process-related uses such as heating of water or buildings, and finally for export across fence lines to neighbouring plants or to municipal uses.

2. Heat capture and use, or transporting heat to neighbouring plants is not the core business of any of the Industrial Heartland companies. They have to see some value in doing this since it adds equipment, complexity and risk to their operations.
3. There are currently no regulations on releasing heat to the atmosphere (as opposed to chemical pollutants). If waste heat was regulated, or waste heat capture was supported by government, it would create an incentive for industry to act.
4. Carrots are better than sticks. It was generally agreed that government support for waste heat capture projects would be better received than regulatory action by government to restrict the emission of waste heat.
5. It would be best if the waste heat could be managed by a third party. That way each company within the Industrial Heartland could deal with a single entity as either a seller or buyer of heat, rather than trying to set up contracts with many different industrial sites within the region.
6. Transporting heat over distances greater than 1 km, especially low temperature heat, is a difficult and expensive proposition since it requires piping infrastructure that does not yet exist.
7. It is much easier to export energy from a site as electricity since the electricity transportation grid already exists. Waste heat can be used to generate electricity given the right temperatures.
8. The forecast for electricity transmission costs suggests increases of 30% over the next 5 years. This may be a good incentive for generating electricity from waste heat for internal uses, or for establishing regional partnerships for electricity production to avoid transmission costs.
9. Waste heat utilization would help companies meet their greenhouse gas reduction targets, however if heat is being transferred between companies there should be clarity on how the GHG credits are allocated.
10. Understand if this could be connected to municipal efforts in City of Edmonton.
11. A lot of pipelines in area already – can we heat anything in these pipelines??
12. Build an “industrial utility” for water that used waste energy, moved water (heat), cleaned water, preserved water.
13. Connect to City of Edmonton EPCOR utility plants → across the river (would crossing the river be an issue?)
14. Cloverbar area (City of Edmonton) – has potential for increasing efficiency of their processes
15. Waste treatment facility (City of Edmonton) – displace natural gas use
16. Waste water is an option as a heat carrier
17. Not a lot of available real estate in Strathcona area.

18. For things like industrial greenhouses to absorb heat and also CO<sub>2</sub> from industrial sites
19. Connect to new developments that are defined in community development plans (ARP)
20. Cooling is needed for several processes since production is limited when Outdoor Air Temperature >25°C.
21. Only small number of days where this is required
22. Ice storage in tanks using absorption chillers could be used
23. Can we use low-grade heat for faster site reclamation of contaminated sites? Could use the low grade heat to support microbial action that cleans up contaminated soils.
24. Thermal energy storage opportunity.
25. Snow storage for summer cooling (there is a Government of Alberta regulation on runoff treatment)..
26. Just tell people it's available – available waste heat – post it's available and see who responds. Energy Portal idea.
27. Regulatory incentives on development tied to industrial system designation change. ISD enables those within area to avoid electricity transmission charges.
28. Municipal incentives / cost breaks
29. Alberta becomes a showcase location as a test centre/location – NCIA – AIHA.
30. Critical to get involved at the scoping and design stages of projects.
31. New furnaces have better metallurgy so can lower temperature of stacks more.
32. Use off-peak electricity to run compressor/vapor compression to upgrade heat.
33. Need energy storage.
34. Geology/hydrogeology in the region is generally poor for thermal storage and requires deep bore holes
35. Maybe day-to-night energy storage using large tanks of liquid.
36. Tank farms may be a good recipient for waste heat, but it is unknown what temperatures are required.
37. Look at possibility of creating an integrated energy utility to enable “plug-and-play” for smaller new entrants. Aim is to try and leverage all the future development going on in the region.

38. Could several companies combine their waste heat to drive an ORC machine?
39. Inter-company information exchange can be challenging.
40. Due to lower returns, companies may need to consider different corporate guidelines or ROI for energy efficiency projects rather than other capital projects.