Identifying Opportunities for Reductions in Energy Consumption and Greenhouse Gas Emissions from Heat Loss by Industry May 2016

Wisconsin Pollution Prevention Grant NP-00E501510-0
Pollution Prevention for Wisconsin Businesses 2015
David S. Liebl, Principal Investigator

The industrial sector is responsible for about 30% of all U.S. energy usage, with about a third of that energy discharged as thermal losses directly to the atmosphere or to cooling systems. The extent to which there are opportunities for Wisconsin industry to reduce or recover this waste heat, and mitigate the associated energy consumption and greenhouse gas emissions (GHG), has been poorly understood.

Working with UW-College of Engineering faculty, we conducted a scoping study to determine the opportunities for and potential cost and GHG reductions from waste heat reduction by Wisconsin manufactures. Specifically we:

1. Developed collaborations with other industrial technical assistance providers in Wisconsin to better understand the application of heat recovery technologies;
2. Surveyed the technology and techniques for heat loss reduction using $P2R_X$, DOE-Industrial Assessment Centers (IAC) and other sources;
3. Identified Wisconsin manufacturing facilities with processes amenable to heat loss reduction;
4. Developed an approach for targeting technical assistance to facilities with potential for reducing energy usage and GHG emission related to heat loss;
5. Investigated the feasibility of estimating the achievable reduction from heat recovery technologies (in metric tons of carbon dioxide equivalent) for the targeted industries.

This report provides the outcomes from this project and describes how other pollution prevention technical assistance providers can identify and address industrial heat loss reduction opportunities.

1) *Develop collaborations with other industrial technical assistance providers in Wisconsin to better understand the application of heat recovery technologies.*

Technical assistance to Wisconsin manufacturers for improving energy efficiency (including heat recovery) is provided by several programs and organizations including: Wisconsin Focus on Energy (subcontractor Leidos Engineering), the Wisconsin Manufacturing Extension Partnership, Wisconsin electrical utilities (subcontractor Franklin Energy Services) and the DOE Industrial Assessment Center at the University of Wisconsin Milwaukee.

We used contacts from these organizations to better understand the landscape of industrial energy assistance in Wisconsin, and to provide feedback on the development of a heat recovery strategy report. The energy assistance providers we worked with included:

Prof. Chris Yingchun Yuan, Director, *UW-Milwaukee DOE-Industrial Assessment Center*

John Nicol and William Lumsden, *Leidos Engineering*

Ed Carroll, Rick Pettibone and Frank Dreher, *Franklin Energy Services*

Jake Oelke, *WPPI Energy*

Masood Akhtar, *Clean Tech Partners*

Randy Bertram and Mark McDermid, *Wisconsin Manufacturing Extension Partnership*

Ted Wilinski, *Milwaukee Area Technical College*

2) *Survey the technology and techniques for heat loss reduction using P2R$_{X}$, DOE-IACs and other sources.*

We did not find information on industrial heat recovery technologies or technical assistance on the P2Rx site or other traditional sources of pollution prevention information. This supports the observation of a disconnect between technical assistance programs for hazardous pollution prevention, and those addressing industrial energy efficiency. Significant resources for identifying waste heat recovery technologies that we did obtain included:

Waste Heat Reduction and Recovery for Improving Furnace Efficiency, Productivity and Emissions Performance, U.S. Department of Energy-Industrial Technologies Program, DOE/GO-102004-1975 November 2004

Opportunity Analysis for Recovering Energy from Industrial Waste Heat and Emissions, Pacific Northwest Laboratories, April 2006

Arzbaecher, Cecilia, E. Fouche, K. Parmenter, *Industrial Waste-Heat Recovery: Benefits and Recent Advancements in Technology and Applications*, ACEEE Summer Study on Energy Efficiency in Industry, 2007

Waste Heat Recovery: Technology and Opportunities in U.S. Industry, 2008, U.S. Department of Energy-Industrial Technologies Program

Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, USEPA Office of Air and Radiation, October 2010

Waste Heat Recovery in Industrial Facilities-Opportunities for Combined Heat and Power and Industrial heat Pumps, Electric Power Research Institute #1020134, December 2010

Waste Heat to Power Market Assessment, Oak Ridge national Laboratory, ORNL/TM-2014/620, March 2015

Barriers to Industrial Energy Efficiency, USDOE, June 2015

Quadrennial Technology Review-An Assessment of Energy Technologies and Research Opportunities, USDOE, September 2015

DOE-Industrial Assessment Centers database, https://iac.university/#database

While each of these resources was informative about technology applications for industrial heat recovery, the DOE-IAC database proved to be the richest source of data. Figure 1 is a screen-shot of the IAC database user interface, queried for the Assessment Recommendation Code (ARC) 2.24XX Heat Recovery. The results show that a total of 6,487 heat recovery recommendations have been recorded, along with each specific recommendation, cost and savings.

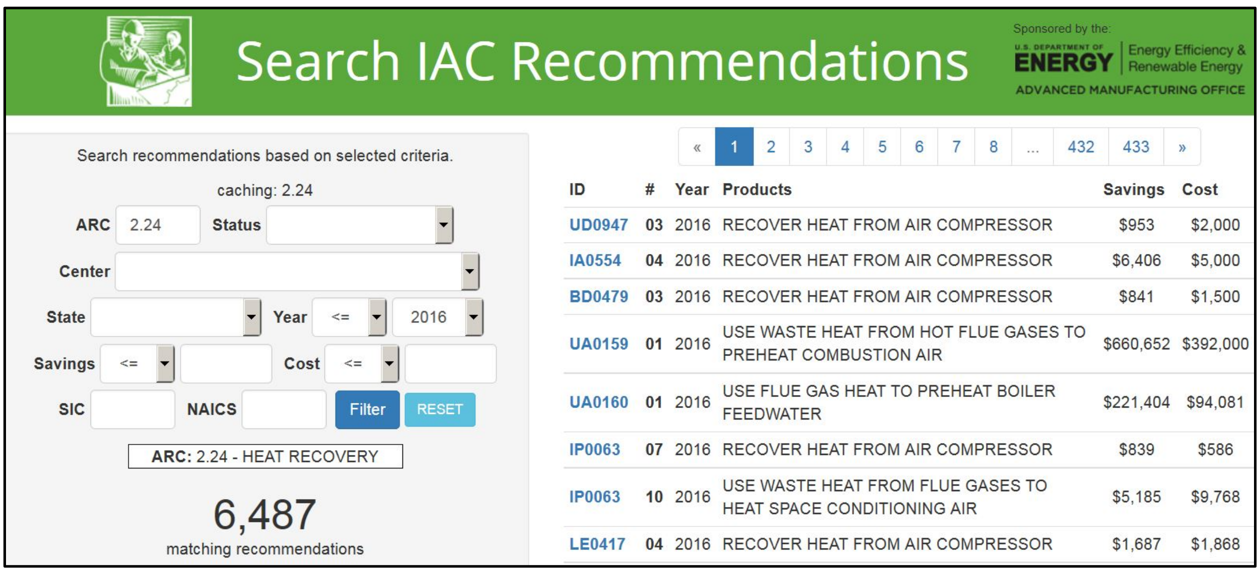


Figure 1.

The IAC database (downloaded in its entirety) was the foundation of the analysis as described in *Identifying Opportunities for Waste Heat Recovery in Wisconsin Industry,* SHWEC, April 2016. From it we were able to derive both the frequency of ARC heat recovery recommendations (Fig. 2) and the frequency of manufacturing SICs (Fig.3 and Append. II) for which those recommendations were made.

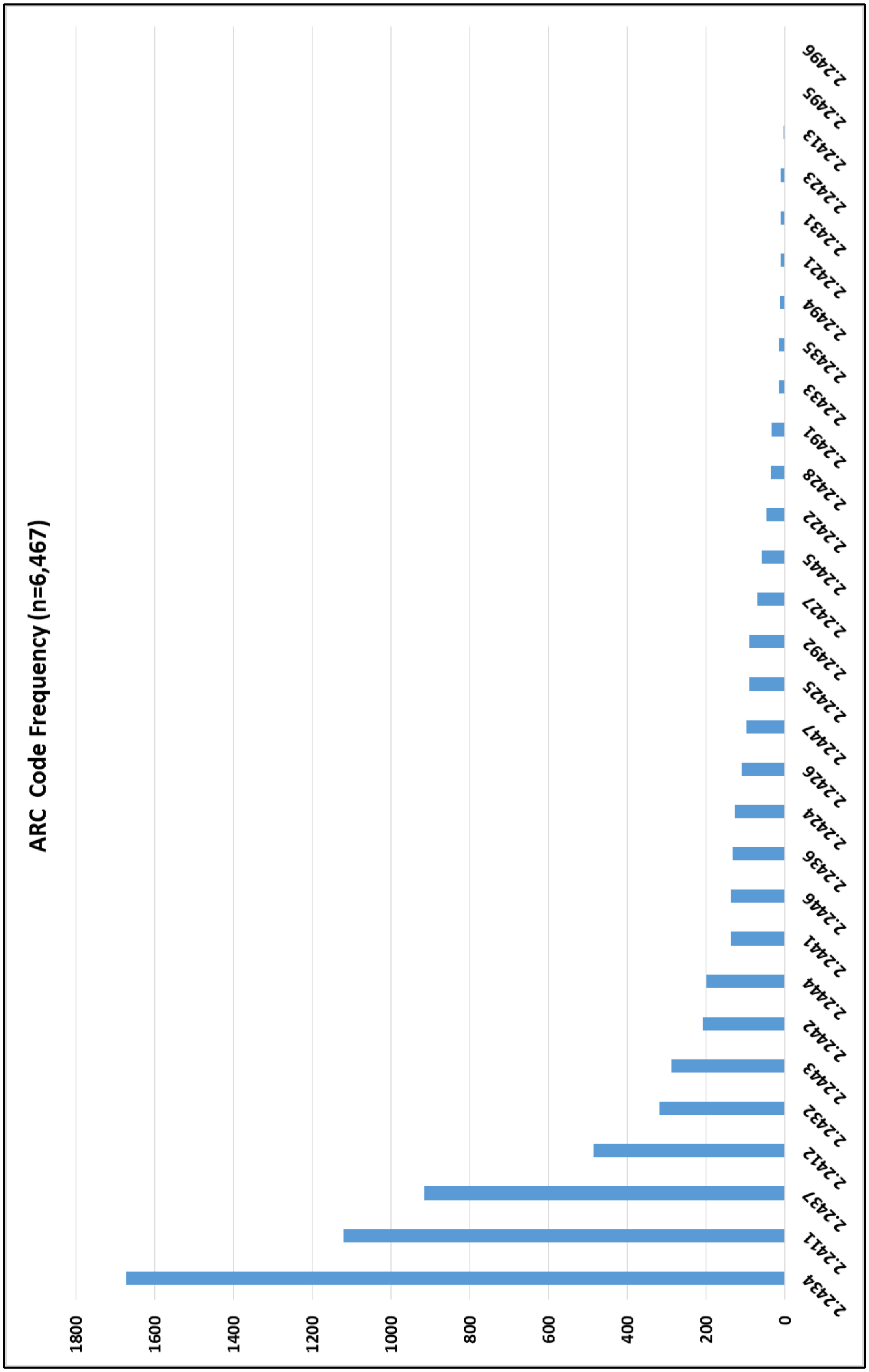

ARC Code Frequency (n=6,467)
0
200
400
600
800
1000
1200
1400
1600
1800
2.2434
2.2411
2.2437
2.2412
2.2432
2.2443
2.2442
2.2444
2.2441
2.2446
2.2436
2.2424
2.2426
2.2447
2.2425
2.2492
2.2427
2.2445
2.2422
2.2428
2.2491
2.2433
2.2435
2.2494
2.2421
2.2431
2.2423
2.2413
2.2495
2.2496

Figure 2.

Figure 2:

ARC	Frequency	Description
2.2434	1673	Recover Heat From Air Compressor
2.2411	1121	Use Waste Heat From Hot Flue Gases To Preheat Combustion Air
2.2437	917	Recover Waste Heat From Equipment
2.2412	486	Use Flue Gas Heat To Preheat Boiler Feedwater
2.2432	318	Recover Heat From Oven Exhaust / Kilns
2.2443	288	Re-Use Or Recycle Hot Or Cold Process Exhaust Air
2.2442	209	Preheat Combustion Air With Waste Heat
2.2444	198	Use Hot Process Fluids To Preheat Incoming Process Fluids
2.2441	138	Preheat Boiler Makeup Water With Waste Process Heat
2.2446	136	Recover Heat From Hot Waste Water
2.2436	132	Recover Heat From Refrigeration Condensers
2.2424	128	Use Heat In Flue Gases To Preheat Products Or Materials
2.2426	109	Use Waste Heat From Flue Gases To Heat Space Conditioning Air
2.2447	98	Heat Water With Exhaust Heat
2.2425	92	Use Flue Gases To Heat Process Or Service Water
2.2492	90	Use “Heat Wheel” Or Other Heat Exchanger To Cross-Exchange Building Exhaust Air With Make-Up Air
2.2427	71	Use Waste Heat From Hot Flue Gases To Preheat Incoming Fluids
2.2445	59	Recover Heat From Exhausted Steam
2.2422	48	Use Waste Heat From Hot Flue Gases To Generate Steam
2.2428	37	Use Flue Gases In Radiant Heater For Space Heating, Ovens, Etc.
2.2491	34	Use Cooling Air Which Cools Hot Work Pieces For Space Heating
2.2433	16	Recover Heat From Engine Exhausts
2.2435	15	Recover Heat From Compressed Air Dryers
2.2494	14	Recover Heat In Domestic Hot Water Going To Drain
2.2421	11	Install Waste Heat Boiler To Provide Direct Power
2.2431	11	Recover Heat From Transformers
2.2423	10	Install Waste Heat Boiler To Produce Steam
2.2413	3	Use Hot Flue Gases To Preheat Wastes For Incinerator Boiler
2.2495	2	Use Exhaust Heat From Building For Snow And Ice Removal
2.2496	2	Heat Service Hot Water With Air Conditioning Equipment

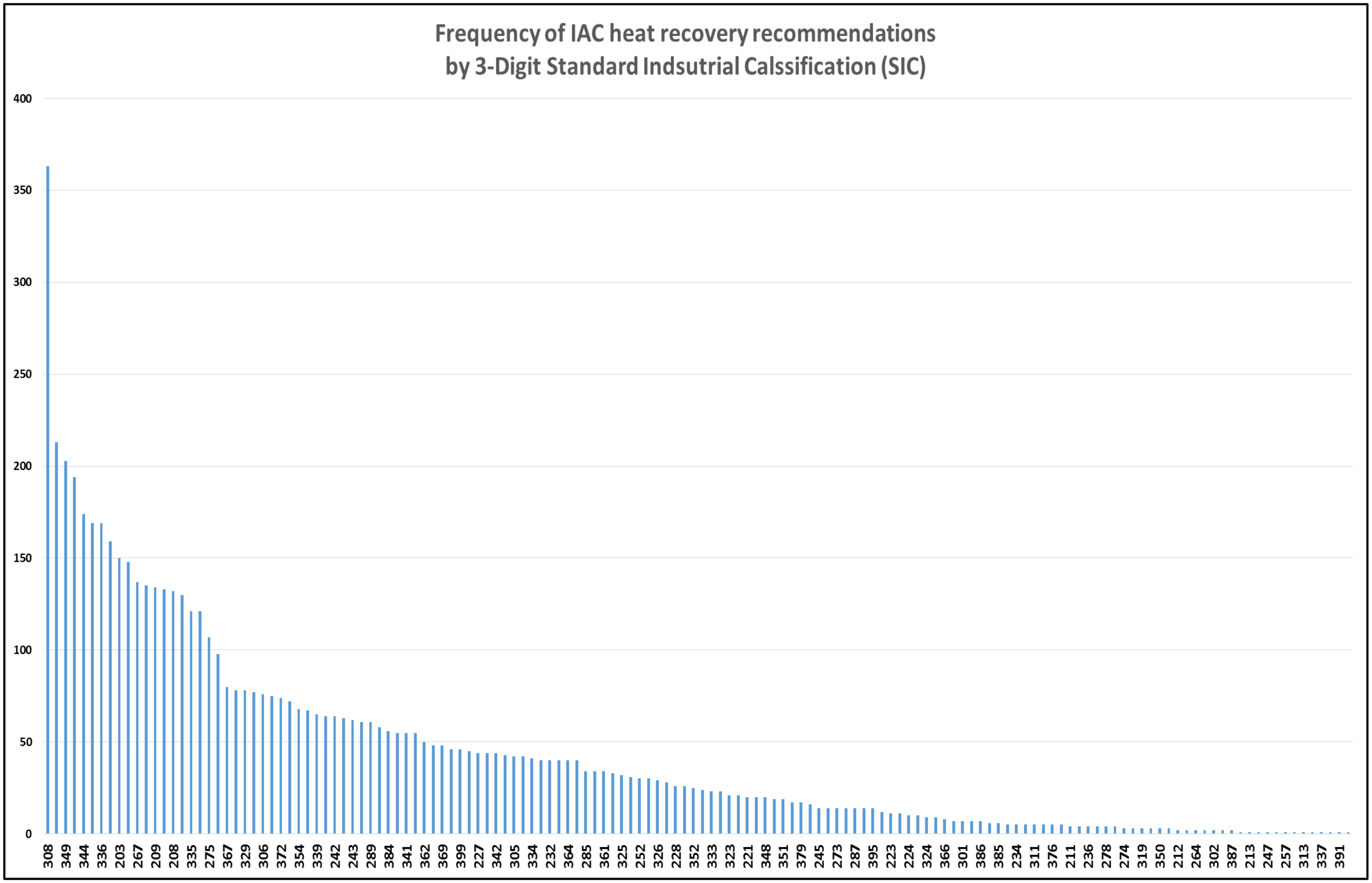

Frequency of IAC heat recovery recommendations
by 3-Digit Standard Indsutrial Calssification (SIC)
400
350
300
250
200
150
100
50
0
308 349 344 336 203 267 209 208 335 275 367 329 306 372 354 339 242 243 289 384 341 362 369 399 227 342 305 334 232 364 285 361 325 252 326 228 352 333 323 221 348 351 379 245 273 287 395 223 224 324 366 301 386 385 234 311 376 211 236 278 274 319 350 212 264 302 387 213 247 257 313 337 391

Figure 3.

This exercise revealed two important factors for the development of the statewide heat recovery opportunity analysis:

- Many IAC heat recovery assessment recommendations are applicable across standard industrial classifications. For example, the most frequent recommendations (e.g. 2.2434 Recover Heat From Air Compressor, or 2.2411 Use Waste Heat From Hot Flue Gases To Preheat Combustion Air) are relevant to nearly every manufacturing facility that uses compressed air, or heats space or water.

- The types of industries (by 3-digit SIC) that receive heat recovery recommendations are varied, both by industry type and by frequency of recommendation.

3) *Identify Wisconsin manufacturing facilities with processes amenable to heat loss reduction.*

The IAC database provides the Standard Industrial Classification (SIC) code for each facility nationally that received an ARC for heat recovery. For the industrial classifications of Wisconsin manufacturers we obtained the National Establishment Time Series (NETS) database (Courtesy of the University of Wisconsin-Extension, Business Dynamics Research Consortium: http://exceptionalgrowth.org/our-databases.iegc) which provides either an SIC or a NAICS (North American Industry Classification System) designation. We joined these data to assign a common industrial classification for each facility for our analysis.

4) *Develop an approach for targeting technical assistance to facilities with potential for reducing energy usage and GHG emission related to heat loss.*

Using the IAC and NETS databases we correlated the significant (>1% frequency) national heat recovery recommendations with significant (>1% of total) Wisconsin industrial sectors (Fig. 4). Appendix III describes the processes of data manipulation to achieve these results.

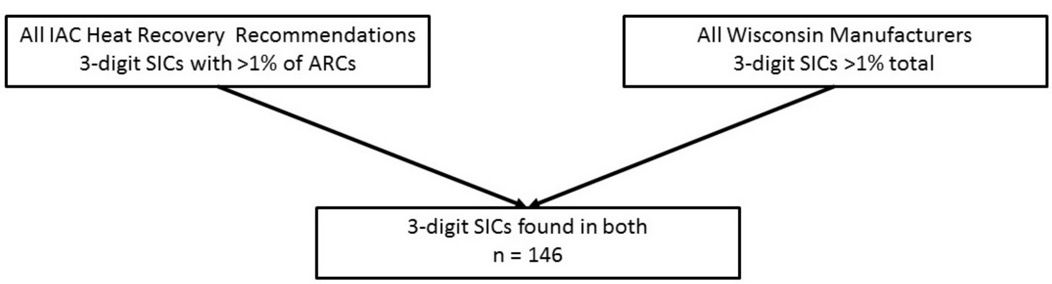


Figure 4.

We used this correlation to identify those heat recovery ARCs that are common to the predominant industrial sectors for Wisconsin manufacturing. The outcome of this exercise is described in *Identifying Opportunities for Waste Heat Recovery in Wisconsin Industry* (Appendix I.), which was distributed to the energy assistance provider contacts for review. Feedback on the analysis included the following comments:

> The [IAC] recommended technologies did not reveal anything new. Most of the options have been recommended by [provider] previously.
>
> Overall, a very favorable reaction to the report. Report reflects [provider's] experience.
>
> [Provider] typically includes heat recovery opportunity analysis as part of any technical assistance interaction.
>
> [Provider's] program occasionally targets heat recovery by SIC (e.g. Asphalt plants).
>
> I would be helpful be able to drill down further into the IAC database to find more specific data on the specifics of the recommendations.
>
> Would like to see more detail from specific projects than is available from the IAC database, e.g. actual project cost and payback period. In [provider's] experience many heat recovery projects have about a five year payback. Implementation of heat recovery projects can require specialized skill and equipment, leading to higher costs. Creative financing often needed.
>
> Develop detailed case studies that can be used by field staff for both specific industries and specific technologies. Should include: facility information, heat recovery technology recommended, calculation spreadsheets, costs and payback, examples of actual implementation, vendors, etc.
>
> IAC could create detailed case study examples for common heat recovery technologies showing actual costs and paybacks.
>
> The report, and underlying IAC information could be very useful as a strategic planning document.
>
> The report is a good tool for identifying heat recovery opportunities within SICs, especially for less experienced staff. Could be used to develop a checklist for technical assistance project development and management.

Marketing heat recovery through the utility rebate programs should be a priority. [Provider] sees substantial opportunity to expand work with industry.

5) *Investigate the feasibility of estimating the achievable reduction from heat recovery technologies (in metric tons of carbon dioxide equivalent) for the targeted industries.*

The DOE-IAC database provides detailed information on the cost, payback period and implementation rate of heat recovery recommendations made as part of IAC assessments (see: Appendix I page 21). However, like other technical assistance providers, the DOE Industrial Assessment Centers track energy use post-assessment. While DOE-IAC is developing an approach that would allow prospective estimates of GHG reductions from heat recovery technologies (Texas A&M IAC personal communication), we were unable to derive information that would allow a such an estimate of GHG reductions from heat recovery opportunities in Wisconsin manufacturing facilities.

<u>Lessons Learned</u>
1) Like many technical assistance providers, energy assistance providers have multiple strategies for choosing which facilities to work with. A typical energy assessment will address all energy usage in a manufacturing facility, including usage where heat recovery is an option. Thus, strategically targeting specific heat reduction technologies may only make sense when:

- A specific heat recovery technology has the potential to result in large reductions in energy usage (e.g. ARC 2.2412 Use Flue Gas to Preheat Boiler Feedwater) in comparison to aggregate reductions from a technology that is widely applicable (e.g. ARC 2.2434 Recover Heat from Air Compressor);

- Technical assistance staff have expertise with a specific heat recovery technology(s), and narrowly focusing their work makes maximum use of that expertise;

- New heat reduction technologies with increased feasibility or cost effectiveness lead to targeted assistance to promote diffusion of those technologies.

2) From the interest shown by the Wisconsin non-IAC energy assistance providers, there is ample opportunity for better communication/coordination between private, state and federal assistance programs. Presumably this is the case for all industrial energy assistance, not simply for waste heat recovery.

3) There are barriers that must be overcome if existing state pollution prevention programs are to effectively work with industry to reduce greenhouse gas emissions through adoption of heat recovery technology:

- Analysis, both technical and economic, of specific heat recovery opportunities requires specific skills and experience with individual manufacturing processes and heat recovery technologies that is not usually found in programs that take a more facility-wide approach to waste reduction.

- An individual facility's opportunity for heat recovery may require long term engineering design and implementation support that is beyond the capacity of traditional hazardous pollution prevention programs.

3) EPA's focus on greenhouse gas emissions, and the desire for state pollution prevention programs to encourage GHG reductions, calls for more awareness between EPA and DOE about their respective industrial assistance programs. The opportunity to leverage the full complement of waste, energy, and pollution reduction for the manufacturing sector is not likely to be realized with the existing programmatic "silos" unless functional partnerships between these programs are established.

Appendices

I. *Identifying Opportunities for Waste Heat Recovery in Wisconsin Industry*, April 2016

II. Manufacturing SICs

III. IAC Heat Recovery Opportunity Analysis

Identifying Opportunities for Waste Heat Recovery in Wisconsin Industry

April 2016

David S. Liebl, University of Wisconsin-Madison, Solid and Hazardous Waste Education Center
Lee DeBaillie, University of Wisconsin-Madison, Engineering Professional Development

In 2008, the U.S. Department of Energy (DOE)-Industrial Technologies Program's reported[1] that the U.S. industrial sector accounts for about one third of the total energy consumed in the United States and is responsible for about one third of fossil fuel related greenhouse gas emissions...(and) estimated that somewhere between 20 to 50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products.

Industrial waste heat can be defined as "… the energy associated with waste streams of air, exhaust gases, and/or liquids that leave the boundaries of an industrial facility and enter the environment….it is implicit that the waste streams eventually mix with atmospheric air or groundwater and that the energy contained within them becomes unavailable as useful energy."[2]

US DOE has identified[1] the major sources of Industrial waste heat as:

Examples of Waste Heat Sources and End-Uses

Waste Heat Sources	Uses for Waste Heat
• Combustion Exhausts:	• Combustion air preheating
Glass melting furnace	• Boiler feedwater preheating
Cement kiln	• Load preheating
Fume incinerator	• Power generation
Aluminum reverberatory furnace	• Steam generation for use in:
Boiler	power generation
• Process off-gases:	mechanical power
Steel electric arc furnace	process steam
Aluminum reverberatory furnace	• Space heating
• Cooling water from:	• Water preheating
Furnaces	• Transfer to liquid or gaseous process streams
Air compressors	
Internal combustion engines	
• Conductive, convective, and radiative losses from equipment:	
Hall-Hèroult cells [a]	
• Conductive, convective, and radiative losses from heated products:	
Hot cokes	
Blast furnace slags [a]	

a. Not currently recoverable with existing technology

In addition to these intensively used or widely occurring heat sources, most industrial facilities will have some manufacturing processes or equipment that create waste heat. However these sources may not lend themselves to waste heat reduction strategies due to their unique nature, lack of technical feasibility for implementing heat recovery, or poor return on investment in a heat recovery technology.

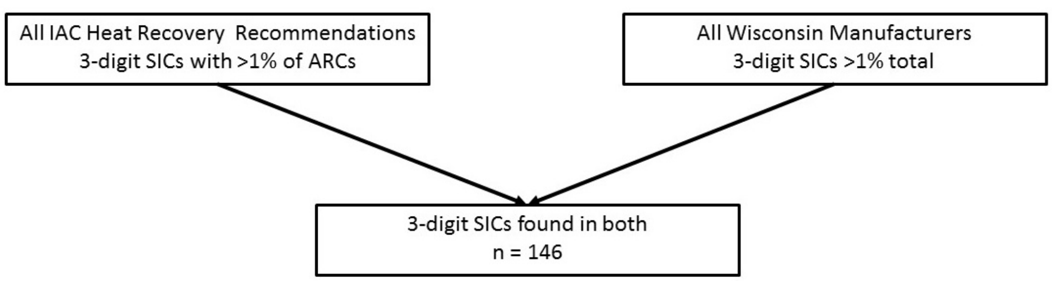
To assist manufacturers in identifying heat recovery opportunities and evaluating both the technical and economic feasibility of heat recovery technologies, the network of DOE-Industrial Assessment Centers (IACs) were formed in 1976. "IACs are teams of university-based faculty and student engineers that provide no-cost energy, productivity, and waste assessments to small and medium sized US manufacturers nationwide."(3) Since inception, the IACs have conducted over 17,000 facility assessments comprising over 130,000 specific recommendations.(4) Of these, over 6,000 recommendations are specific to industrial heat recovery.

This report utilizes the accumulated experience of IACs across the US to identify opportunities for providing industrial waste heat recovery technical assistance to manufacturers in Wisconsin. The approach used is as follows:

1. Extract heat recovery assessment recommendations (ARCs) from the IAC database, determine the frequency of each type of recommendation, and the industry receiving assistance by Standard Industrial Classification (SIC).

2. Use a database of WI Industry(5) to identify the SIC and frequency of manufactures in Wisconsin.

3. Correlate significant (>1%) numbers of national heat recovery recommendations with significant (>1%) numbers of Wisconsin industrial sectors.



4. Use this correlation to identify ARCs that are common to many industrial sectors, and to identify ARCs that seem to be predominant for some SICs

5. Use IAC data from completed assessments to estimate the cost benefit and implementation rate from implementing heat recovery technologies.

6. Identify specific industrial sectors or heat recovery technologies that would be appropriate for reducing heat loss and energy use by Wisconsin manufacturers.

Using Industrial Classification Systems

The US-Office of Management and Budget created a Standard Industrial Classification (SIC) system in 1939 to facilitate the analysis of economic trends for American industry. Last revised in 1987, this system comprises major divisions (e.g. Division D. Manufacturing), Major Divisions with two-digit designations (e.g. SIC 20xx Food and Kindred Products), Industry Groups with three-digit designations (e.g. SIC 201x Meat Products) and specific industry descriptions with four-digit designations (e.g. SIC 2011 Meat Packing Plants).

This analysis correlates the IAC ARCs with three digit SICs to provide some degree of specificity as to industrial activity, while avoiding creating uninterpretable results caused by using overly specific four-digit SICs. Having determined the frequency of ARCs for a given Industry Group (3-digit), four-digit SICs are used to describe the specific industries within each Group receiving heat recovery recommendations.

Note: The Standard Industrial Classification system has been superseded by the North American Industry Classification System (NAICS). However, the Doe-IAC database is based on SIC, and so that system has been used for this analysis.

See also:
https://www.census.gov/history/www/innovations/data_collection/classifying_businesses_1.html

Sources and References

1. *Waste Heat Recovery: Technology and Opportunities in U.S. Industry*, 2008, U.S. Department of Energy-Industrial Technologies Program

2. Arzbaecher, Cecilia, E. Fouche, K. Parmenter, *Industrial Waste-Heat Recovery: Benefits and Recent Advancements in Technology and Applications*, 2007, ACEEE Summer Study on Energy Efficiency in Industry

3. *IAC Centers*, https://iac.university/

4. *IAC Database*, https://iac.university/#database

5. *National Establishment Time Series (NETS) database,* Courtesy of the University of Wisconsin-Extension, Business Dynamics Research Consortium: http://exceptionalgrowth.org/our-databases.iegc

Identifying Opportunities for Waste Heat recovery in Wisconsin Industry

Part 2 - ARC to SIC Correlation Analysis Discussion

One hundred forty six 3-digit SICs, correlating to three hundred fourteen North American Industry Classification System (NAICS) codes, met the test of greater than 1% frequency of IAC waste heat recovery assessment recommendations nationally, and also a greater than 1% frequency of Wisconsin manufacturing facilities (see: *4-SIC Key 3-23-16.xlsx*).

The description of the IAC heat recovery recommendations (ARC2), with the frequency (number) of those recommendations for SICs exceeding the 1% threshold for Wisconsin industry are shown below:

ARC2	Frequency	Description
2.2434	1673	Recover Heat From Air Compressor
2.2411	1121	Use Waste Heat From Hot Flue Gases To Preheat Combustion Air
2.2437	917	Recover Waste Heat From Equipment
2.2412	486	Use Flue Gas Heat To Preheat Boiler Feed Water
2.2432	318	Recover Heat From Oven Exhaust / Kilns
2.2443	288	Re-Use Or Recycle Hot Or Cold Process Exhaust Air
2.2442	209	Preheat Combustion Air With Waste Heat
2.2444	198	Use Hot Process Fluids To Preheat Incoming Process Fluids
2.2441	138	Preheat Boiler Makeup Water With Waste Process Heat
2.2446	136	Recover Heat From Hot Waste Water
2.2436	132	Recover Heat From Refrigeration Condensers
2.2424	128	Use Heat In Flue Gases To Preheat Products Or Materials
2.2426	109	Use Waste Heat From Flue Gases To Heat Space Conditioning Air
2.2447	98	Heat Water With Exhaust Heat
2.2425	92	Use Flue Gases To Heat Process Or Service Water
2.2492	90	Use “Heat Wheel” Or Other Heat Exchanger To Cross-Exchange Building Exhaust Air With Make-Up Air
2.2427	71	Use Waste Heat From Hot Flue Gases To Preheat Incoming Fluids
2.2445	59	Recover Heat From Exhausted Steam
2.2422	48	Use Waste Heat From Hot Flue Gases To Generate Steam
2.2428	37	Use Flue Gases In Radiant Heater For Space Heating, Ovens, Etc.
2.2491	34	Use Cooling Air Which Cools Hot Work Pieces For Space Heating
2.2433	16	Recover Heat From Engine Exhausts
2.2435	15	Recover Heat From Compressed Air Dryers
2.2494	14	Recover Heat In Domestic Hot Water Going To Drain
2.2421	11	Install Waste Heat Boiler To Provide Direct Power
2.2431	11	Recover Heat From Transformers
2.2423	10	Install Waste Heat Boiler To Produce Steam
2.2413	3	Use Hot Flue Gases To Preheat Wastes For Incinerator Boiler
2.2495	2	Use Exhaust Heat From Building For Snow And Ice Removal
2.2496	2	Heat Service Hot Water With Air Conditioning Equipment

Grouped by 3-digit SIC (with 4-digit SIC identified) the national frequency >1% of IAC heat recovery recommendations have been charted for the following Wisconsin industry sectors (>1%).
See: *Frequency of IAC Recs and WI SICs over 1 percent - figures 3-21-16.docx*

3-digit SIC >1% IAC and WI SIC>1%

201 Meat Packing Plants
202 Natural, Processed, and Imitation Cheese
203 Canned, Frozen and Preserved Fruits Vegetables and Food Specialties
204 Grain Mill Products
205 Bakery Products
208 Beverages
209 Miscellaneous Food Preparations
242 Sawmills and Planing Mills
243 Millwork, Veneer, Plywood and Structural Wood Members
251 Household Furniture, NEC
267 Converted Paperboard Products Except Containers and Boxes
275 Commercial Printing
283 Drugs
286 Industrial Organic Chemicals
306 Fabricated Rubber Products, NEC
308 Miscellaneous Plastics Products
329 Abrasive, Asbestos and Miscellaneous Nonmetallic Mineral Products
339 Primary Metal Products, NEC
344 Fabricated Structural Metal Products
346 Metal Forgings and Stampings
347 Coating Engraving and Allied Services
349 Miscellaneous Fabricated Metal Products
353 Construction Mining and Materials handling Machinery and Equipment
354 Metalworking Machinery and Equipment
358 Refrigeration and Service Industry Machinery
359 Miscellaneous Industrial and Commercial Machinery and Equipment
367 Electronic Components and Accessories
371 Transportation Equipment

Discussion

As one might expect, several heat recovery recommendations (e.g. ARC 2.2434, 2.2411, 2.2437) apply widely across manufacturing sectors due to the common use of equipment such as air compressors and furnaces or boilers. These types of opportunities rate highly for IAC assessments across the US, and Wisconsin should be no exception to their applicability.

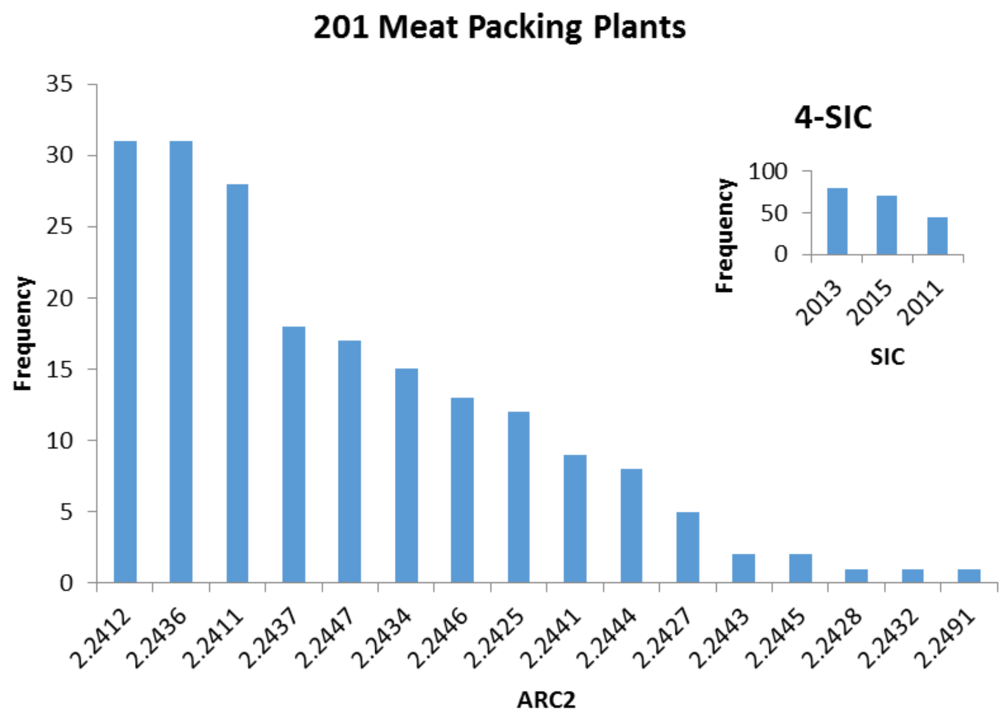
Reviewing the charts of the frequency of waste heat recovery ARCs in the significant (>1%) Wisconsin SICs illustrates several instances arising from this analysis:

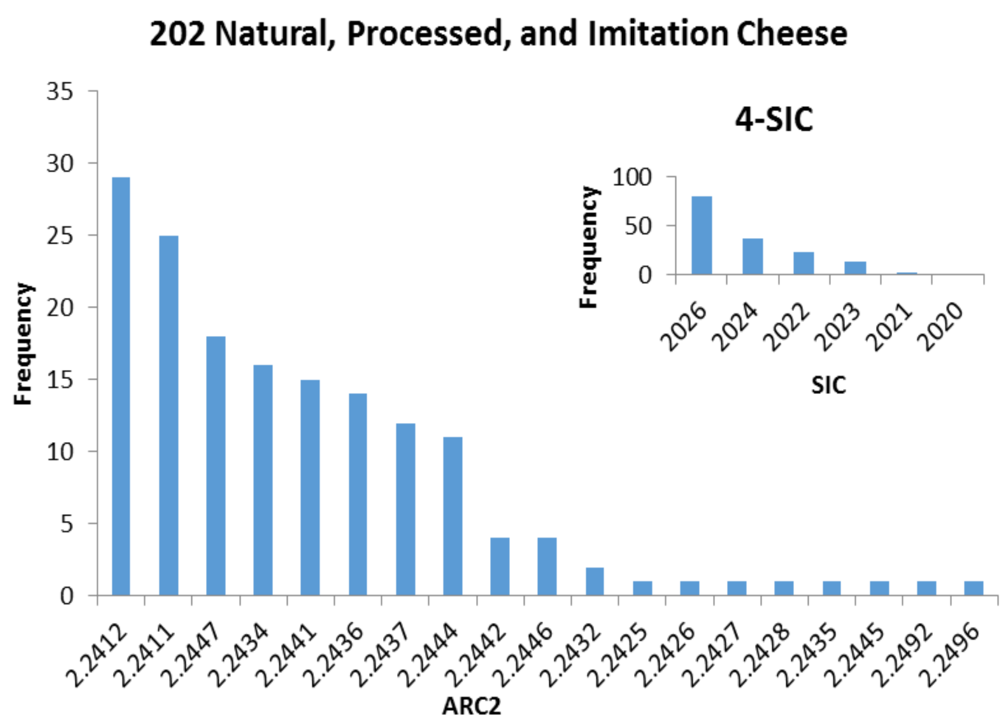
- For some sectors (e.g. SIC 371 Transportation Equipment) the industrial classification encompasses such a broad range of manufacturing facilities, materials, processes and products that no group of ARCs stand out as being advantageous to that sector.

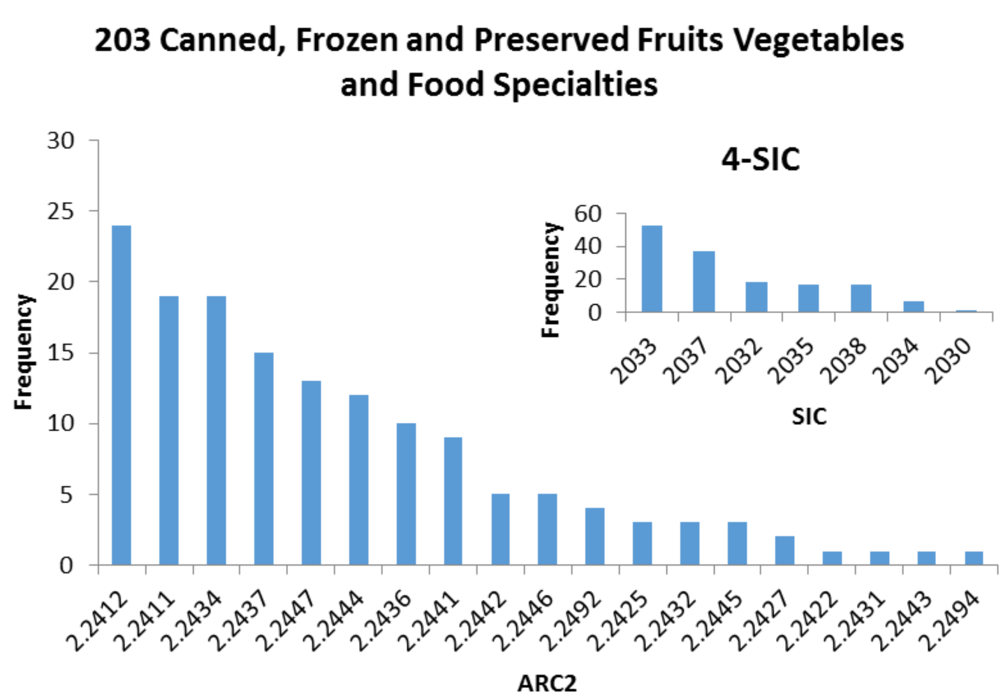
- Other more specific SIC groupings (e.g. 2243 Millwork and 251 Household Furniture) do appear to have ARCs (e.g. 2.2437) with significant opportunities for waste heat recovery for those industries.

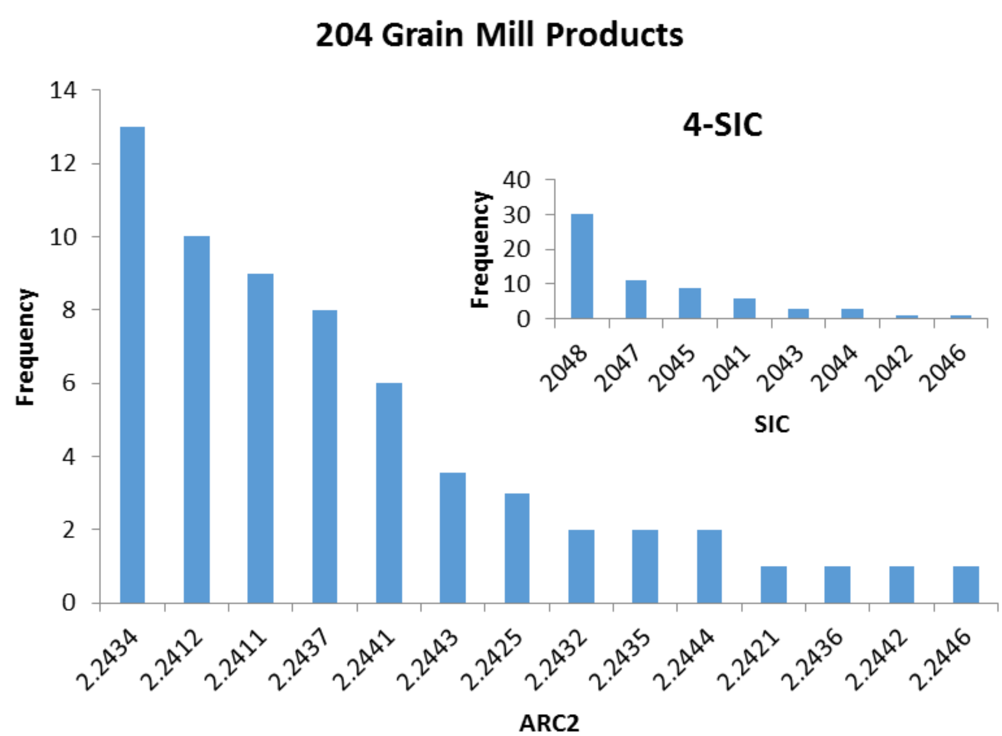
- Some sectors, particularly in the food products industry (SICs: 201, 202, 203, 204, 205, 208, 209) have many ARCs that are commonly recommended to reduce waste heat, underscoring the need for a comprehensive assessment of waste heat recovery opportunities in those facilities.

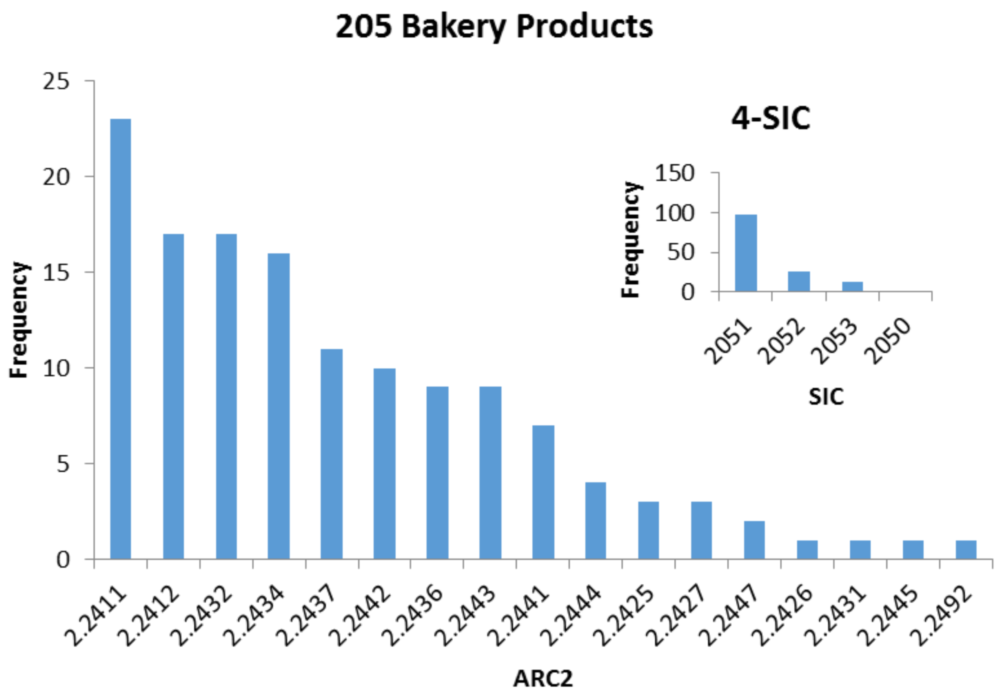
This approach illustrates the use of a comparison between the national level IAC heat recovery recommendation frequency and the frequency by SIC of Wisconsin manufacturing facilities in Wisconsin, to identify potential strategies for providing waste heat recovery technical assistance to Wisconsin industry. Other approaches to analyzing the data may also prove fruitful. For example, choosing a specific industry sector below the 1% SIC threshold may provide more specific insights in advance of performing the actual energy assessment.

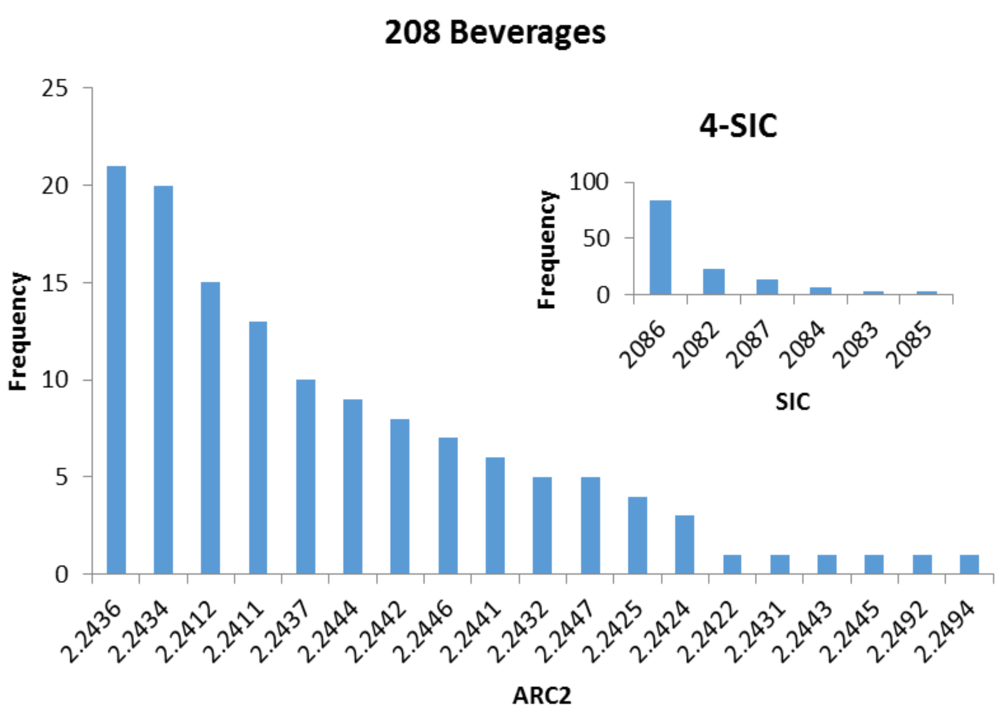

201 Meat Packing Plants
35
30
25
20
15
10
5
0
Frequency
2.2412
2.2436
2.2411
2.2437
2.2447
2.2434
2.2446
2.2425
2.2441
2.2444
2.2427
2.2443
2.2445
2.2428
2.2432
2.2491
ARC2
4-SIC
100
50
0
Frequency
2013
2015
2011
SIC

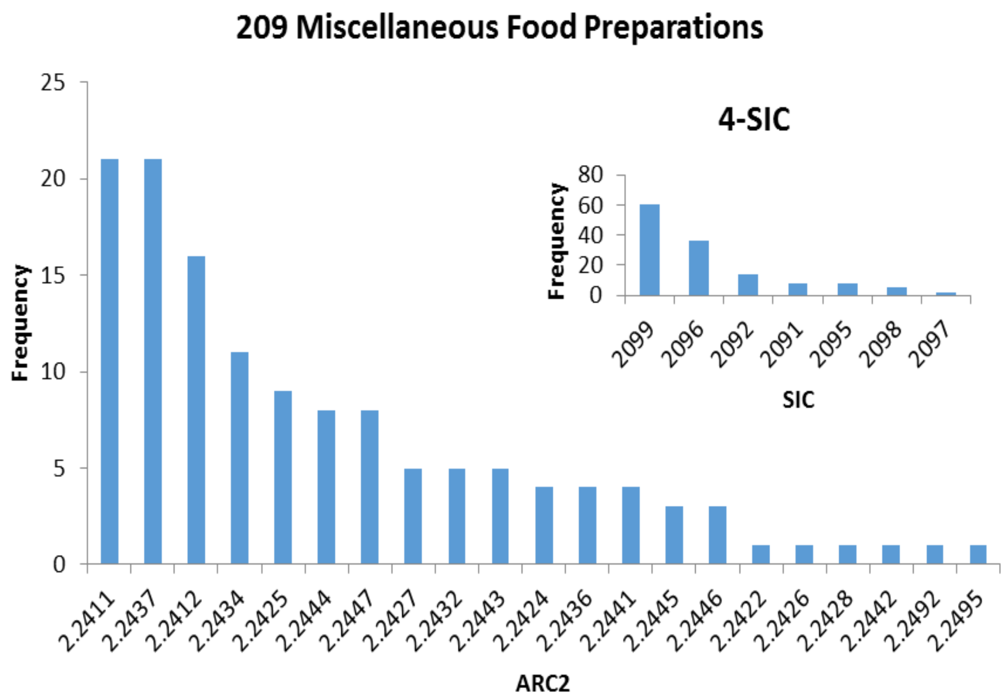

202 Natural, Processed, and Imitation Cheese
35
30
25
20
15
10
5
0
Frequency
2.2412
2.2411
2.2447
2.2434
2.2441
2.2436
2.2437
2.2444
2.2442
2.2446
2.2432
2.2425
2.2426
2.2427
2.2428
2.2435
2.2445
2.2492
2.2496
ARC2
4-SIC
100
50
0
Frequency
2026
2024
2022
2023
2021
2020
SIC

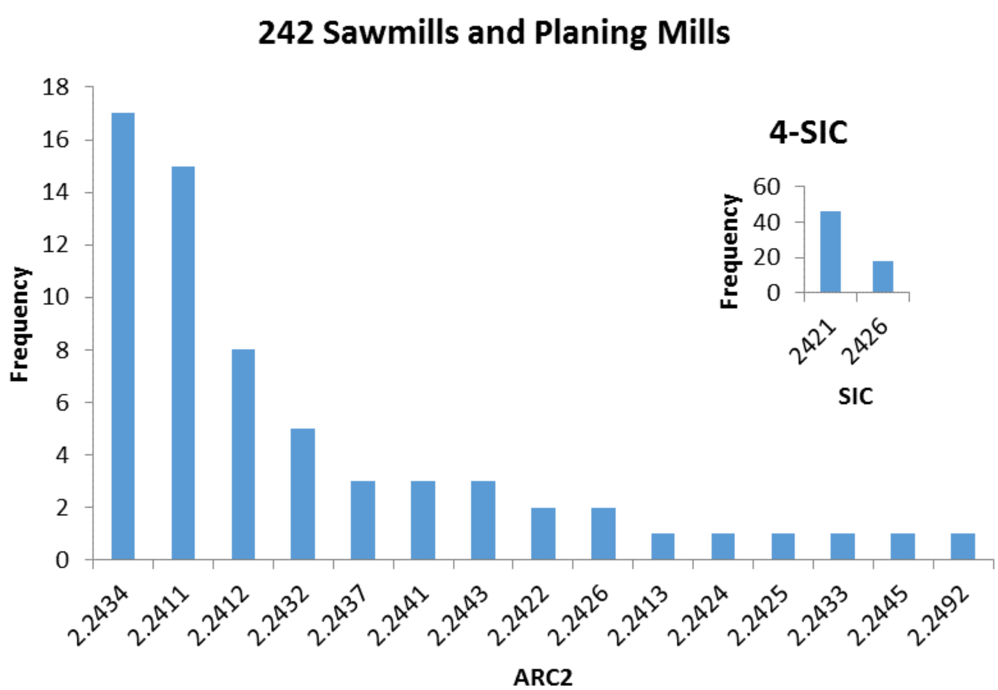

203 Canned, Frozen and Preserved Fruits Vegetables and Food Specialties
Frequency
30
25
20
15
10
5
0
2.2412
2.2411
2.2434
2.2437
2.2447
2.2444
2.2436
2.2441
2.2442
2.2446
2.2492
2.2425
2.2432
2.2445
2.2427
2.2422
2.2431
2.2443
2.2494
ARC2
4-SIC
Frequency
60
40
20
0
2033
2037
2032
2035
2038
2034
2030
SIC

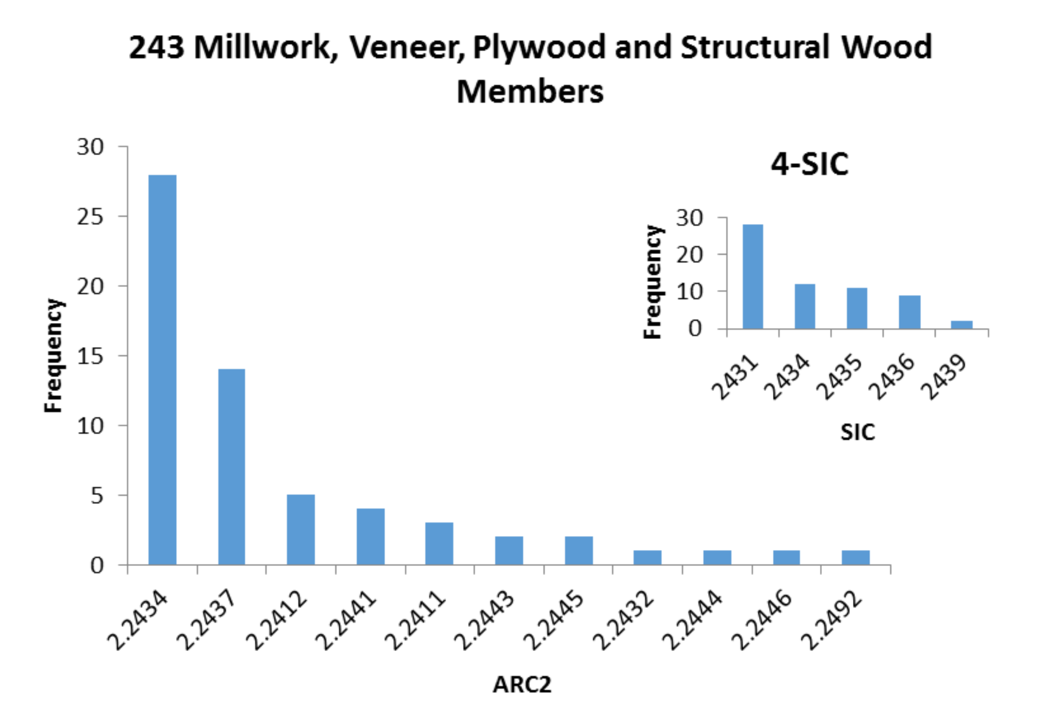

204 Grain Mill Products
Frequency
14
12
10
8
6
4
2
0
2.2434
2.2412
2.2411
2.2437
2.2441
2.2443
2.2425
2.2432
2.2435
2.2444
2.2421
2.2436
2.2442
2.2446
ARC2
4-SIC
Frequency
40
30
20
10
0
2048
2047
2045
2041
2043
2044
2042
2046
SIC

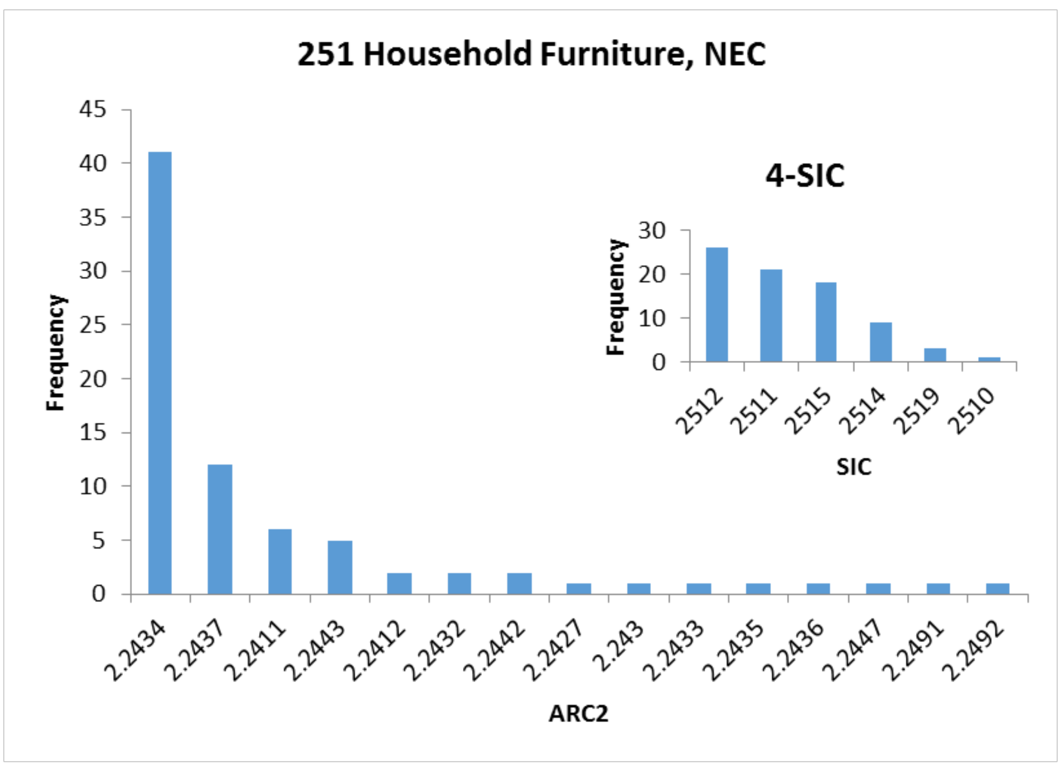

205 Bakery Products
4-SIC
Frequency
150
100
50
0
2051
2052
2053
2050
SIC
25
20
15
10
5
0
2.2411
2.2412
2.2432
2.2434
2.2437
2.2442
2.2436
2.2443
2.2441
2.2444
2.2425
2.2427
2.2447
2.2426
2.2431
2.2445
2.2492
ARC2

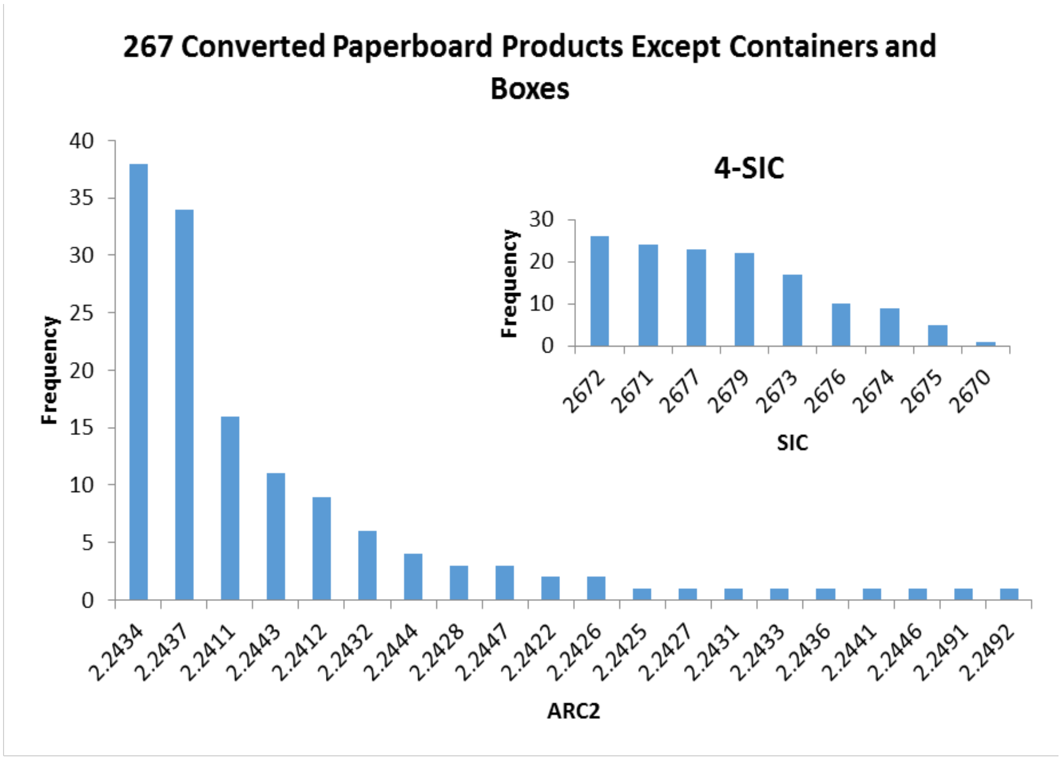

208 Beverages
4-SIC
Frequency
100
50
0
2086
2082
2087
2084
2083
2085
SIC
25
20
15
10
5
0
2.2436
2.2434
2.2412
2.2411
2.2437
2.2444
2.2442
2.2446
2.2441
2.2432
2.2447
2.2425
2.2424
2.2422
2.2431
2.2443
2.2445
2.2492
2.2494
ARC2

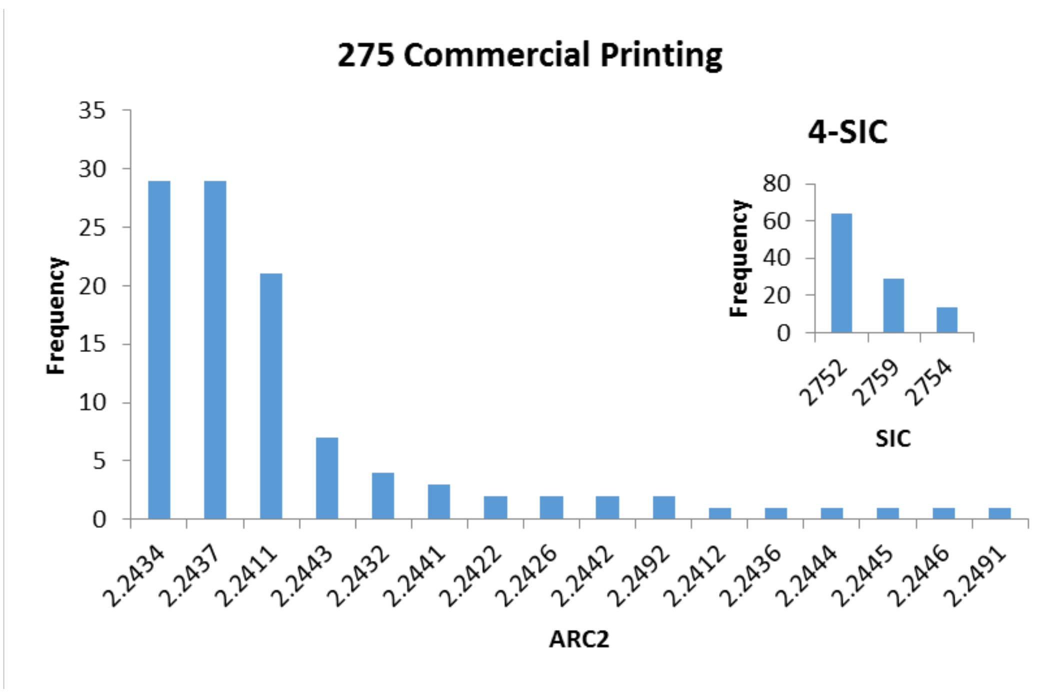

209 Miscellaneous Food Preparations
Frequency
25
20
15
10
5
0
2.2411
2.2437
2.2412
2.2434
2.2425
2.2444
2.2447
2.2427
2.2432
2.2443
2.2424
2.2436
2.2441
2.2445
2.2446
2.2422
2.2426
2.2428
2.2442
2.2492
2.2495
ARC2
4-SIC
Frequency
80
60
40
20
0
2099
2096
2092
2091
2095
2098
2097
SIC

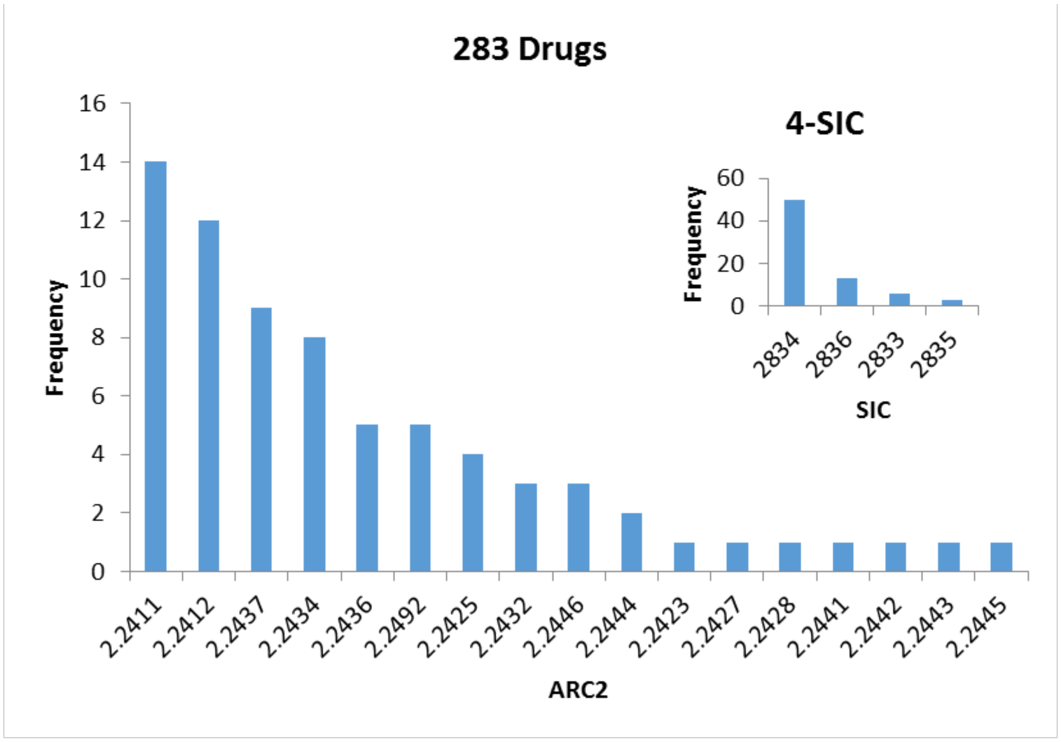

242 Sawmills and Planing Mills
Frequency
18
16
14
12
10
8
6
4
2
0
2.2434
2.2411
2.2412
2.2432
2.2437
2.2441
2.2443
2.2422
2.2426
2.2413
2.2424
2.2425
2.2433
2.2445
2.2492
ARC2
4-SIC
Frequency
60
40
20
0
2421
2426
SIC

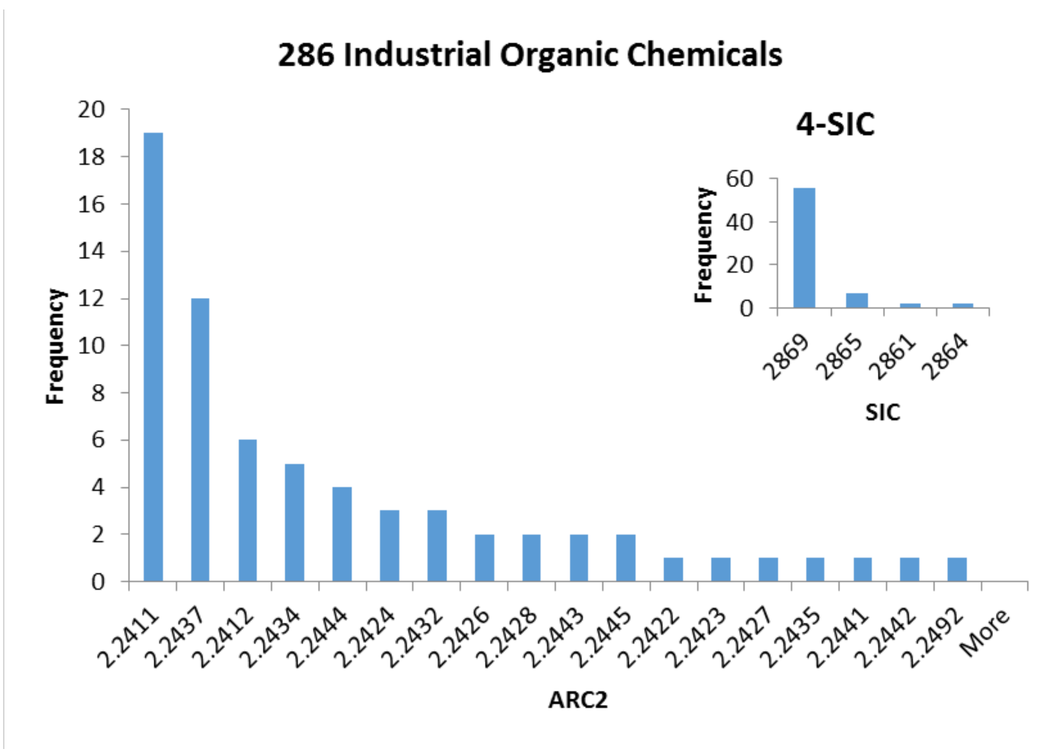

243 Millwork, Veneer, Plywood and Structural Wood Members
Frequency
30
25
20
15
10
5
0
2.2434
2.2437
2.2412
2.2441
2.2411
2.2443
2.2445
2.2432
2.2444
2.2446
2.2492
ARC2
4-SIC
Frequency
30
20
10
0
2431
2434
2435
2436
2439
SIC

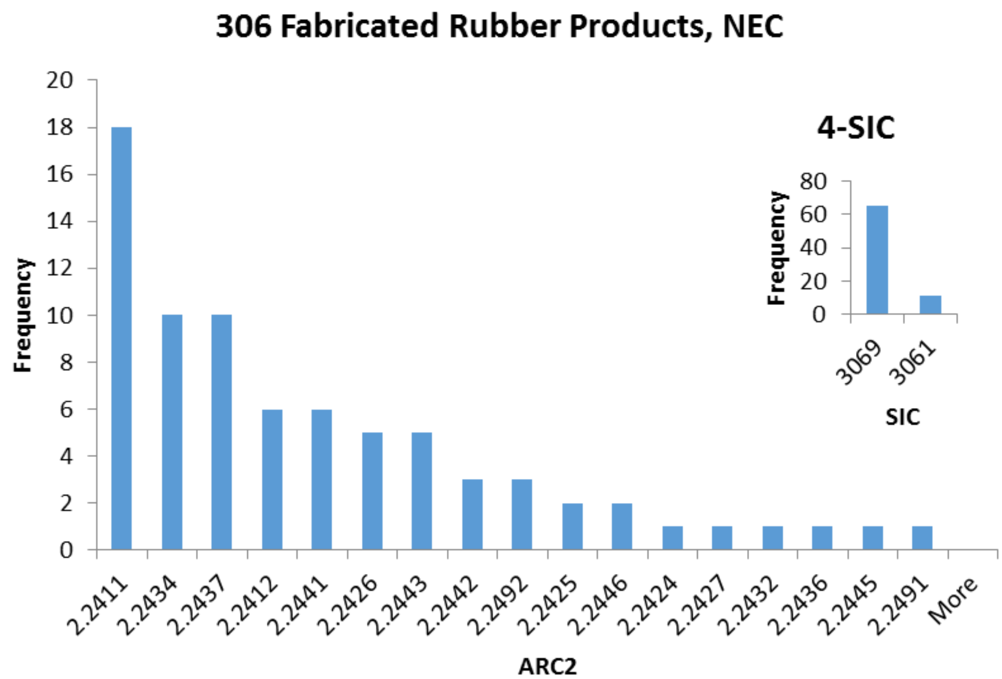

251 Household Furniture, NEC
Frequency
45
40
35
30
25
20
15
10
5
0
2.2434
2.2437
2.2411
2.2443
2.2412
2.2432
2.2442
2.2427
2.243
2.2433
2.2435
2.2436
2.2447
2.2491
2.2492
ARC2
4-SIC
Frequency
30
20
10
0
2512
2511
2515
2514
2519
2510
SIC

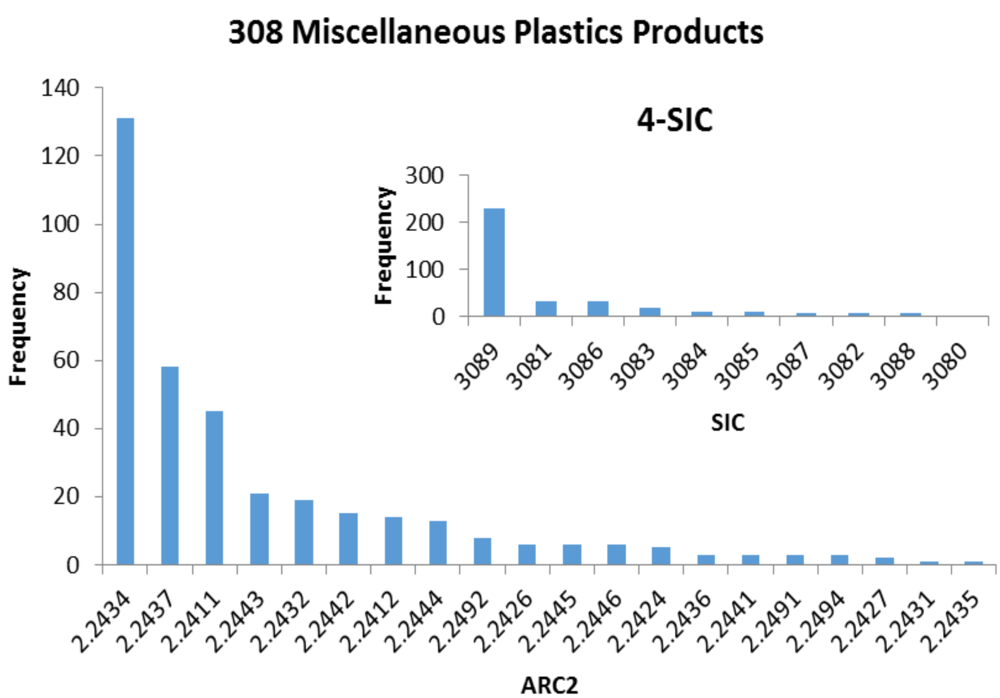

267 Converted Paperboard Products Except Containers and Boxes
4-SIC
Frequency
SIC
2672
2671
2677
2679
2673
2676
2674
2675
2670
ARC2
2.2434
2.2437
2.2411
2.2443
2.2412
2.2432
2.2444
2.2428
2.2447
2.2422
2.2426
2.2425
2.2427
2.2431
2.2433
2.2436
2.2441
2.2446
2.2491
2.2492

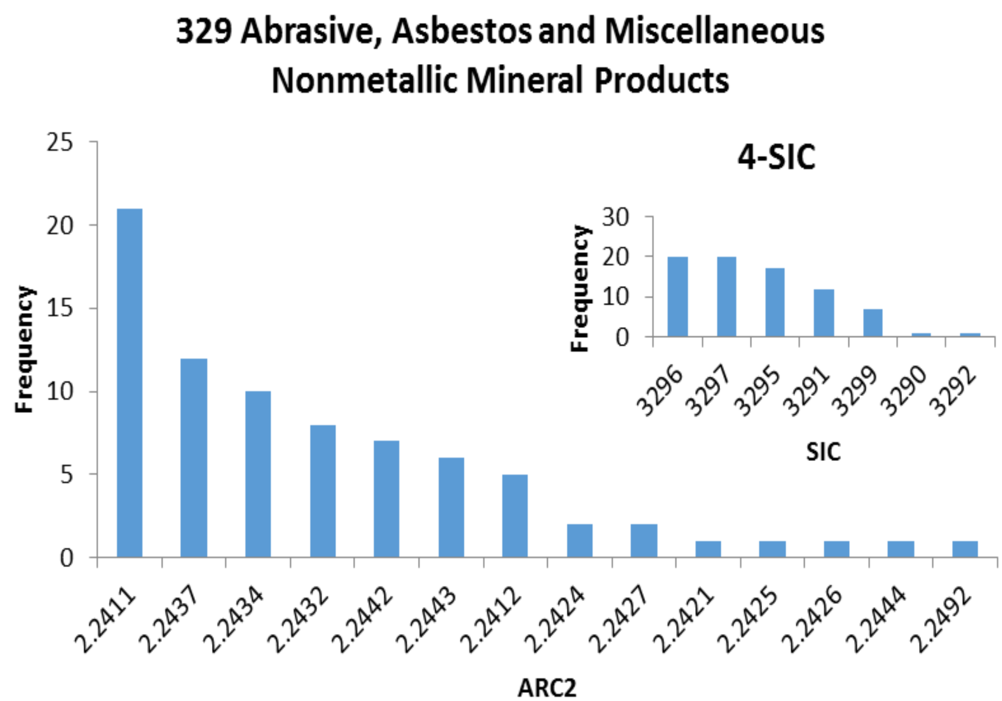

275 Commercial Printing
4-SIC
Frequency
SIC
2752
2759
2754
ARC2
2.2434
2.2437
2.2411
2.2443
2.2432
2.2441
2.2422
2.2426
2.2442
2.2492
2.2412
2.2436
2.2444
2.2445
2.2446
2.2491

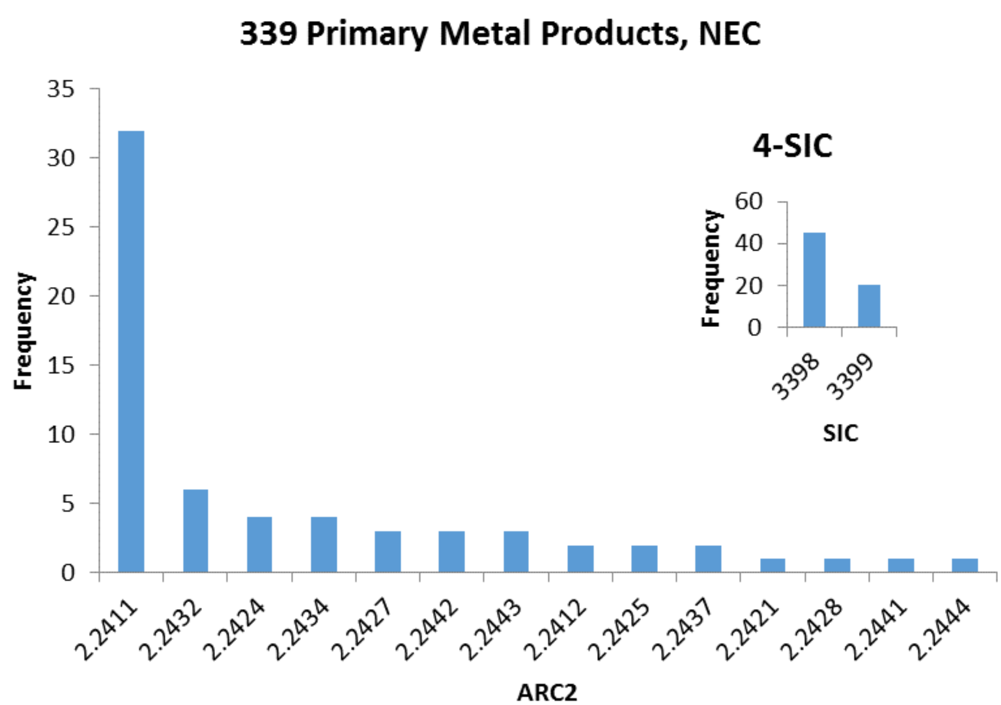

283 Drugs
Frequency
ARC2
2.2411
2.2412
2.2437
2.2434
2.2436
2.2492
2.2425
2.2432
2.2446
2.2444
2.2423
2.2427
2.2428
2.2441
2.2442
2.2443
2.2445
4-SIC
Frequency
SIC
2834
2836
2833
2835

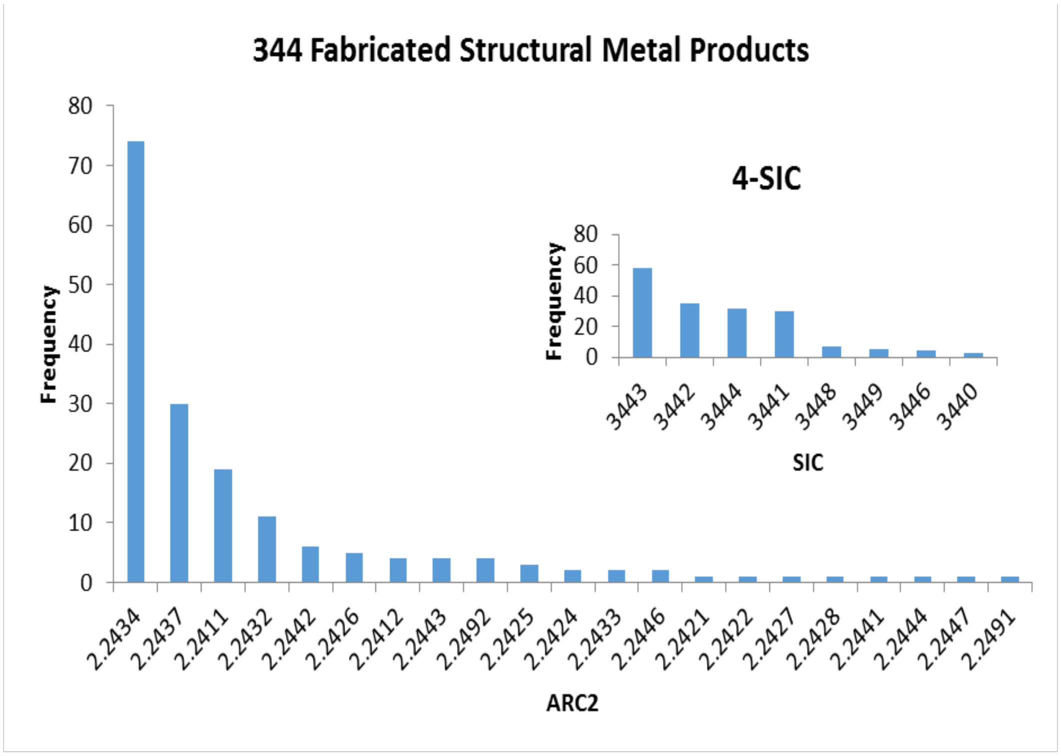

286 Industrial Organic Chemicals
Frequency
ARC2
2.2411
2.2437
2.2412
2.2434
2.2444
2.2424
2.2432
2.2426
2.2428
2.2443
2.2445
2.2422
2.2423
2.2427
2.2435
2.2441
2.2442
2.2492
More
4-SIC
Frequency
SIC
2869
2865
2861
2864

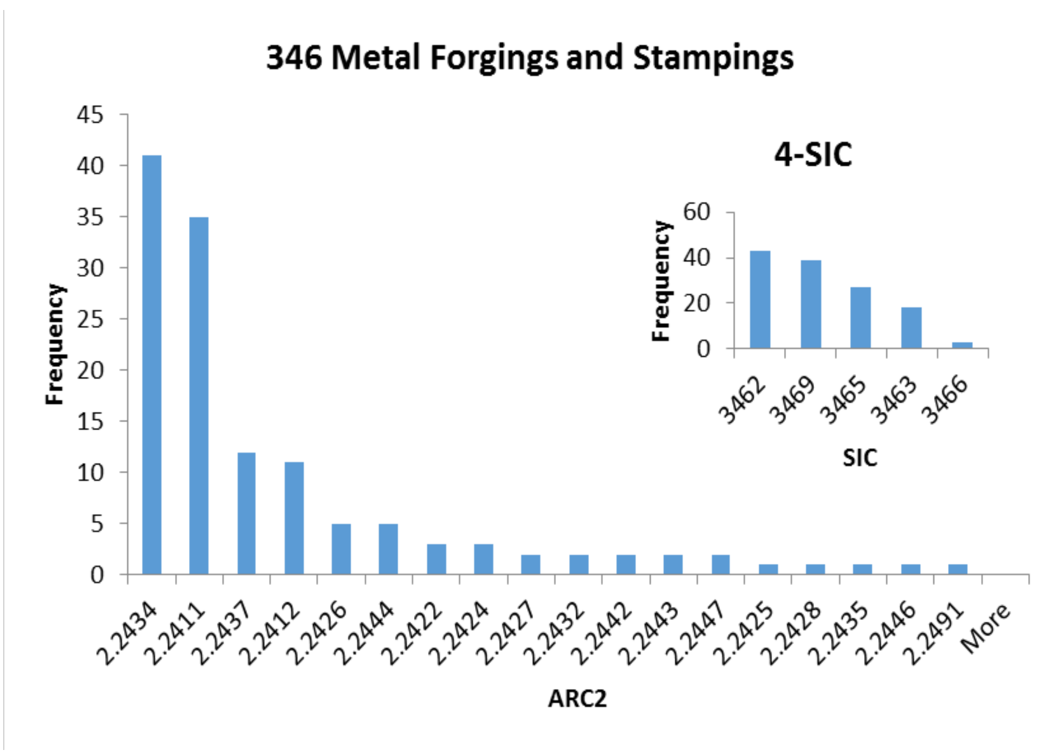

306 Fabricated Rubber Products, NEC
Frequency
ARC2
2.2411
2.2434
2.2437
2.2412
2.2441
2.2426
2.2443
2.2442
2.2492
2.2425
2.2446
2.2424
2.2427
2.2432
2.2436
2.2445
2.2491
More
4-SIC
Frequency
SIC
3069
3061

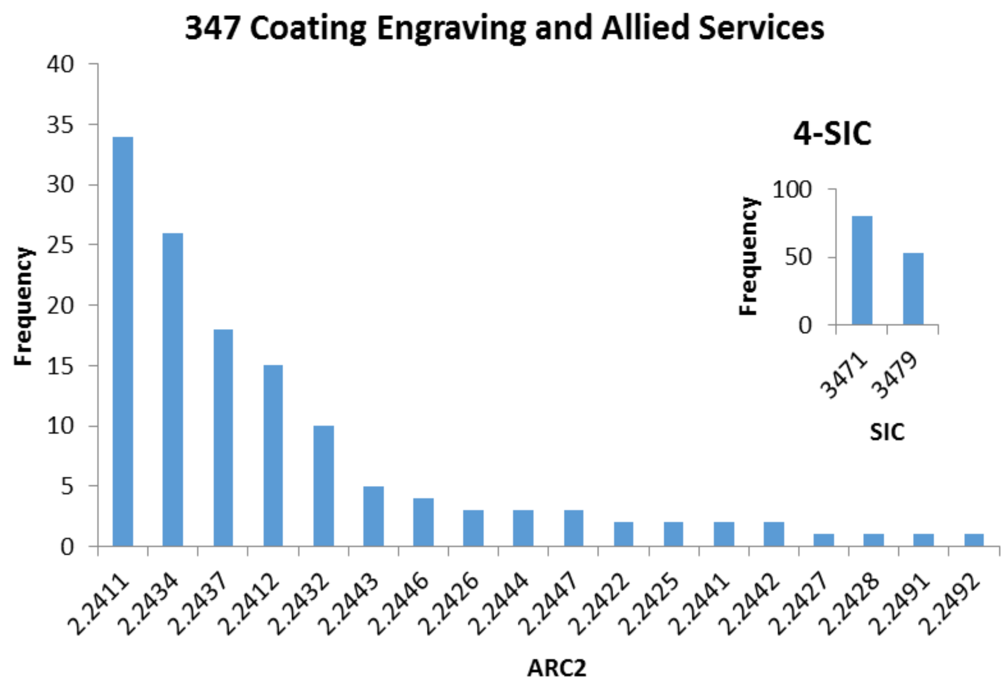

308 Miscellaneous Plastics Products
Frequency
ARC2
2.2434
2.2437
2.2411
2.2443
2.2432
2.2442
2.2412
2.2444
2.2492
2.2426
2.2445
2.2446
2.2424
2.2436
2.2441
2.2491
2.2494
2.2427
2.2431
2.2435
4-SIC
Frequency
SIC
3089
3081
3086
3083
3084
3085
3087
3082
3088
3080

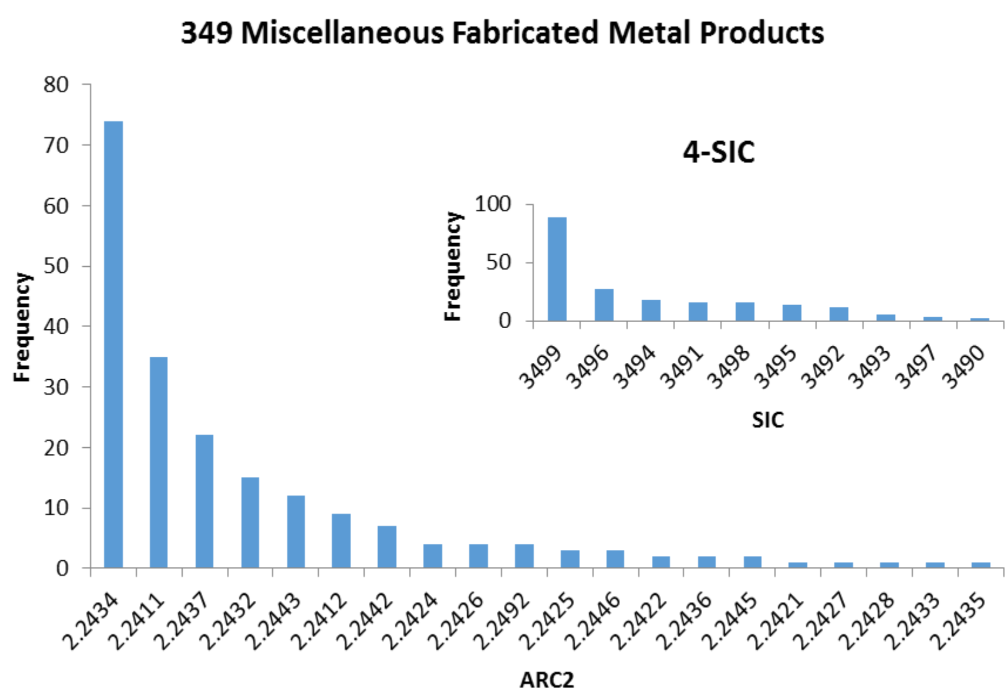

329 Abrasive, Asbestos and Miscellaneous Nonmetallic Mineral Products
Frequency
25
20
15
10
5
0
2.2411
2.2437
2.2434
2.2432
2.2442
2.2443
2.2412
2.2424
2.2427
2.2421
2.2425
2.2426
2.2444
2.2492
ARC2
4-SIC
30
20
10
0
3296
3297
3295
3291
3299
3290
3292
SIC

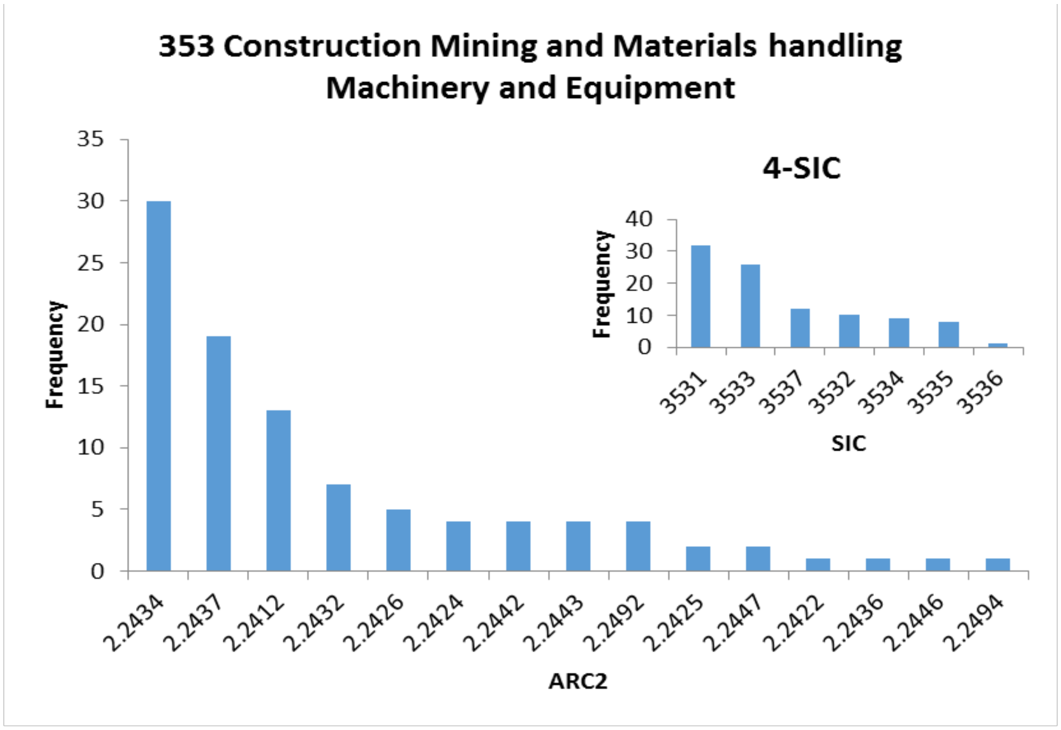

339 Primary Metal Products, NEC
Frequency
35
30
25
20
15
10
5
0
2.2411
2.2432
2.2424
2.2434
2.2427
2.2442
2.2443
2.2412
2.2425
2.2437
2.2421
2.2428
2.2441
2.2444
ARC2
4-SIC
60
40
20
0
3398
3399
SIC

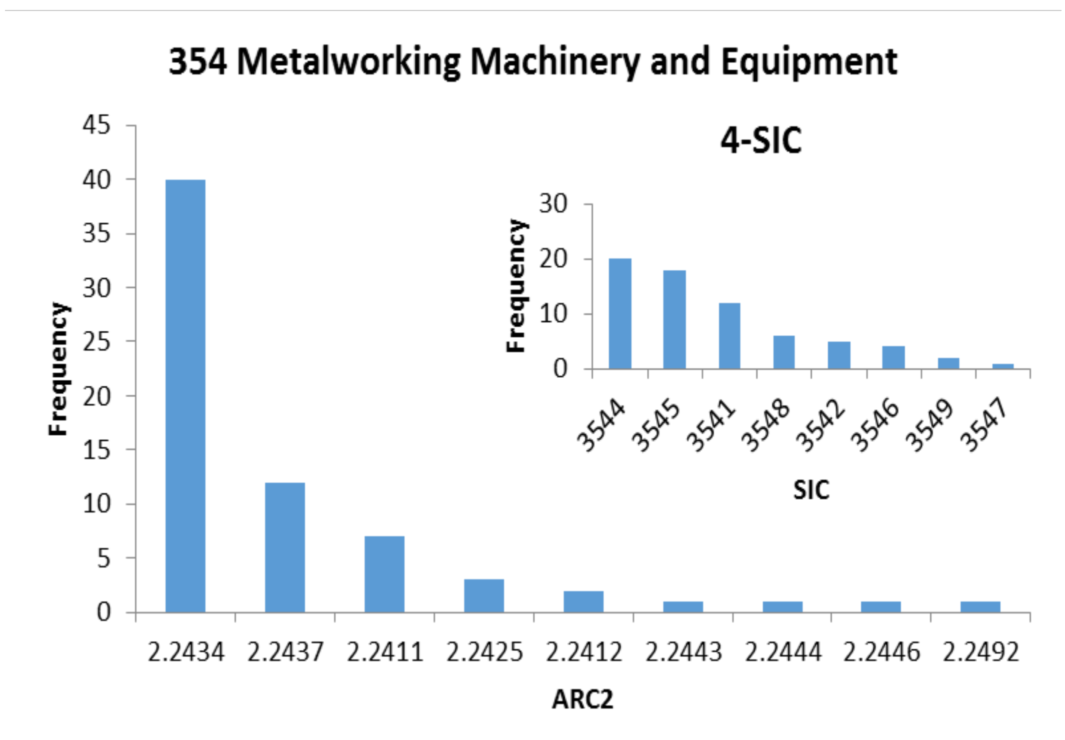

344 Fabricated Structural Metal Products
Frequency
ARC2
2.2434
2.2437
2.2411
2.2432
2.2442
2.2426
2.2412
2.2443
2.2492
2.2425
2.2424
2.2433
2.2446
2.2421
2.2422
2.2427
2.2428
2.2441
2.2444
2.2447
2.2491
4-SIC
SIC
3443
3442
3444
3441
3448
3449
3446
3440

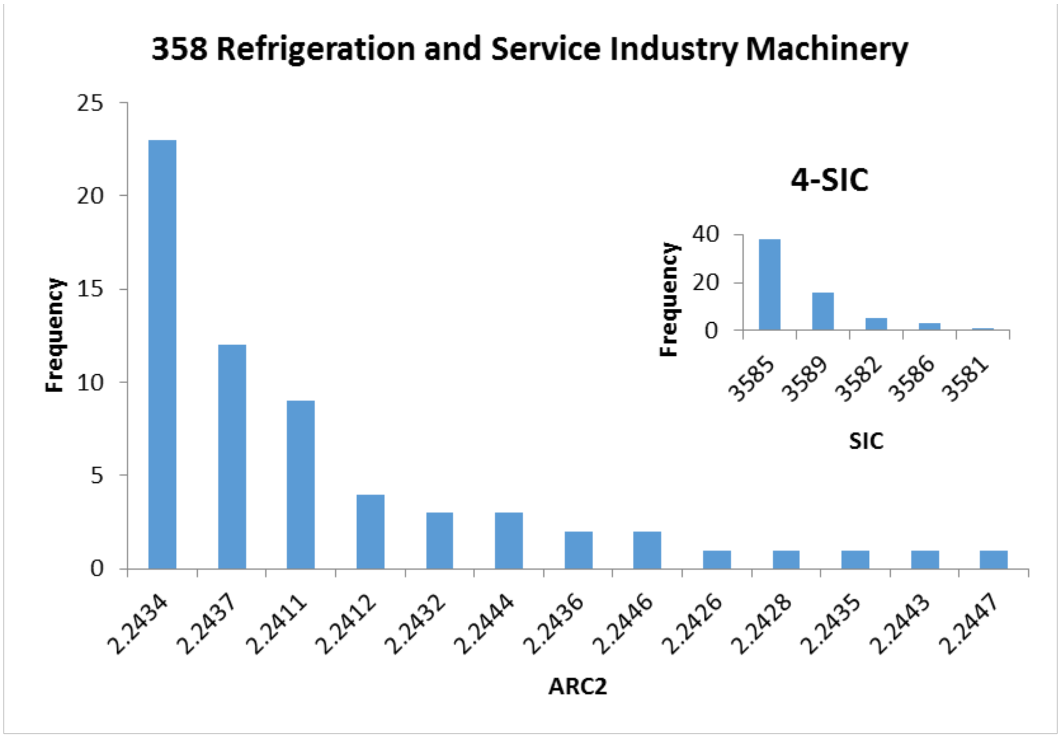

346 Metal Forgings and Stampings
Frequency
ARC2
2.2434
2.2411
2.2437
2.2412
2.2426
2.2444
2.2422
2.2424
2.2427
2.2432
2.2442
2.2443
2.2447
2.2425
2.2428
2.2435
2.2446
2.2491
More
4-SIC
SIC
3462
3469
3465
3463
3466

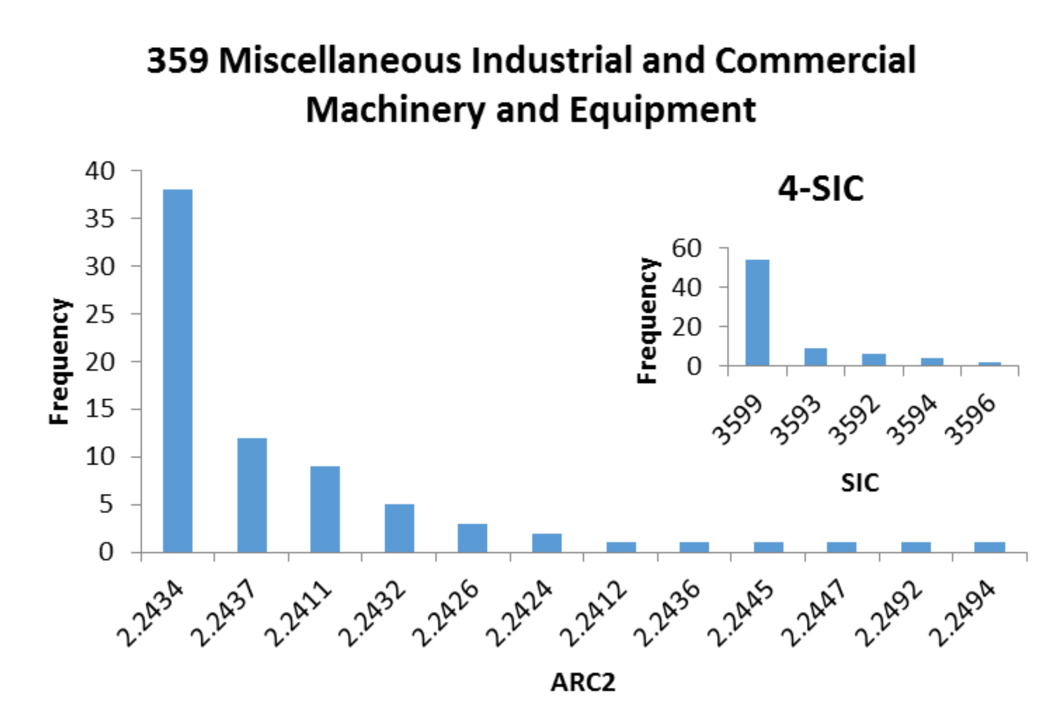

347 Coating Engraving and Allied Services
Frequency
40
35
30
25
20
15
10
5
0
2.2411
2.2434
2.2437
2.2412
2.2432
2.2443
2.2446
2.2426
2.2444
2.2447
2.2422
2.2425
2.2441
2.2442
2.2427
2.2428
2.2491
2.2492
ARC2
4-SIC
Frequency
100
50
0
3471
3479
SIC

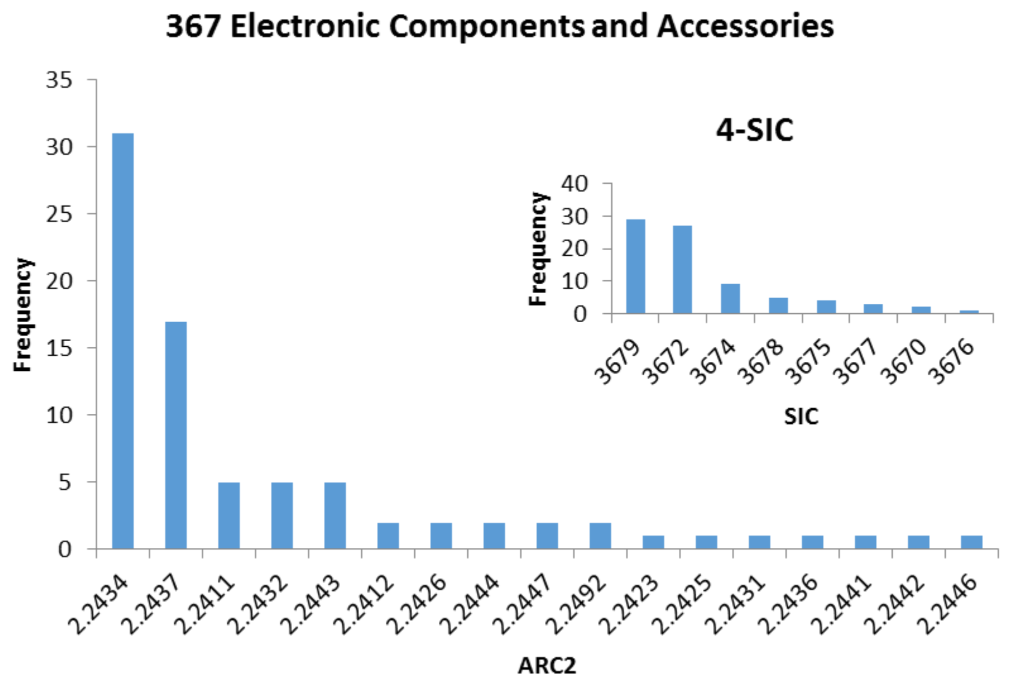

349 Miscellaneous Fabricated Metal Products
Frequency
80
70
60
50
40
30
20
10
0
2.2434
2.2411
2.2437
2.2432
2.2443
2.2412
2.2442
2.2424
2.2426
2.2492
2.2425
2.2446
2.2422
2.2436
2.2445
2.2421
2.2427
2.2428
2.2433
2.2435
ARC2
4-SIC
Frequency
100
50
0
3499
3496
3494
3491
3498
3495
3492
3493
3497
3490
SIC

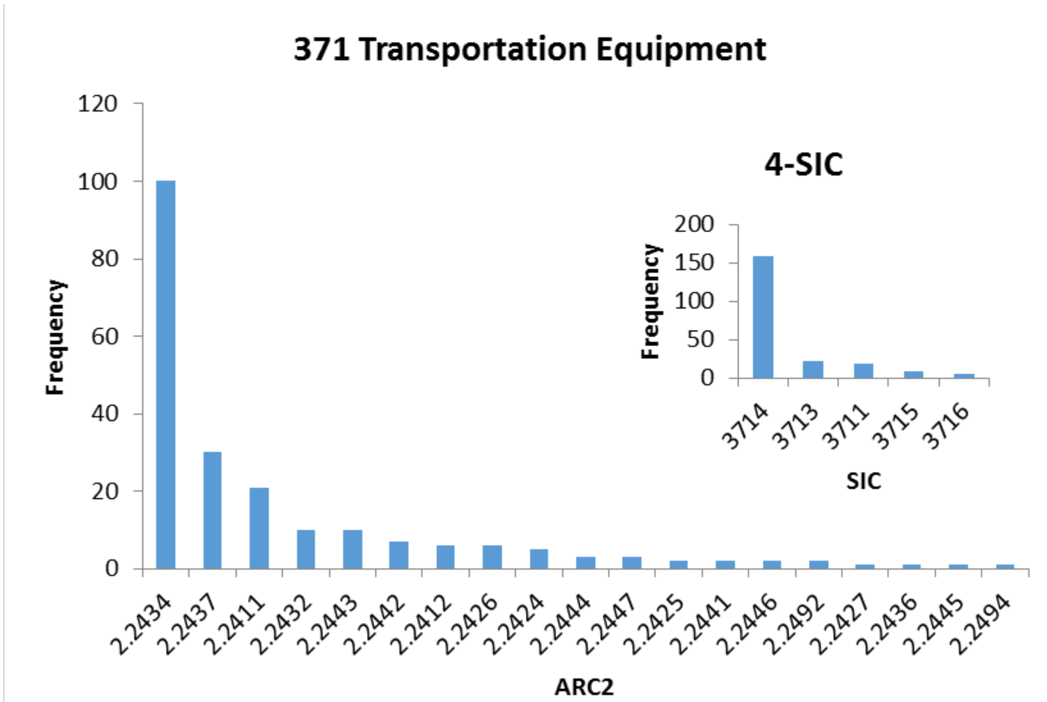

353 Construction Mining and Materials handling Machinery and Equipment
Frequency
ARC2
2.2434
2.2437
2.2412
2.2432
2.2426
2.2424
2.2442
2.2443
2.2492
2.2425
2.2447
2.2422
2.2436
2.2446
2.2494
4-SIC
Frequency
SIC
3531
3533
3537
3532
3534
3535
3536


354 Metalworking Machinery and Equipment
Frequency
ARC2
2.2434
2.2437
2.2411
2.2425
2.2412
2.2443
2.2444
2.2446
2.2492
4-SIC
Frequency
SIC
3544
3545
3541
3548
3542
3546
3549
3547


358 Refrigeration and Service Industry Machinery
Frequency
ARC2
2.2434
2.2437
2.2411
2.2412
2.2432
2.2444
2.2436
2.2446
2.2426
2.2428
2.2435
2.2443
2.2447
4-SIC
Frequency
SIC
3585
3589
3582
3586
3581


359 Miscellaneous Industrial and Commercial Machinery and Equipment
Frequency
ARC2
2.2434
2.2437
2.2411
2.2432
2.2426
2.2424
2.2412
2.2436
2.2445
2.2447
2.2492
2.2494
4-SIC
Frequency
SIC
3599
3593
3592
3594
3596


367 Electronic Components and Accessories
Frequency
ARC2
2.2434
2.2437
2.2411
2.2432
2.2443
2.2412
2.2426
2.2444
2.2447
2.2492
2.2423
2.2425
2.2431
2.2436
2.2441
2.2442
2.2446
4-SIC
Frequency
SIC
3679
3672
3674
3678
3675
3677
3670
3676


371 Transportation Equipment
Frequency
ARC2
2.2434
2.2437
2.2411
2.2432
2.2443
2.2442
2.2412
2.2426
2.2424
2.2444
2.2447
2.2425
2.2441
2.2446
2.2492
2.2427
2.2436
2.2445
2.2494
4-SIC
Frequency
SIC
3714
3713
3711
3715
3716

Part 3 – Examples of Heat Recovery ARC Payback and Implementation

ARC	Description	Recc'd	Average Savings	Average Cost	Average Payback	Imp Rate
2.2411	Use Waste Heat From Hot Flue Gases To Preheat Combustion Air	1,121	$36,726	$47,910	1.7	17.60%
2.2412	Use Flue Gas Heat To Preheat Boiler Feedwater	486	$19,278	$26,108	2.2	25.80%
2.2421	Install Waste Heat Boiler To Provide Direct Power	11	$71,763	$341,435	3.1	20.00%
2.2422	Use Waste Heat From Hot Flue Gases To Generate Steam	48	$52,503	$52,443	1.7	28.30%
2.2423	Install Waste Heat Boiler To Produce Steam	10	$339,451	$726,025	2	33.30%
2.2424	Use Heat In Flue Gases To Preheat Products Or Materials	128	$78,148	$99,679	1.8	20.90%
2.2425	Use Flue Gases To Heat Process Or Service Water	92	$39,911	$51,745	1.9	24.70%
2.2426	Use Waste Heat From Flue Gases To Heat Space Conditioning Air	109	$22,375	$23,063	2.1	25.30%
2.2427	Use Waste Heat From Hot Flue Gases To Preheat Incoming Fluids	71	$51,701	$47,289	1.6	32.30%
2.2428	Use Flue Gases In Radiant Heater For Space Heating, Ovens, Etc	37	$23,784	$26,920	2.2	33.30%
2.2431	Recover Heat From Transformers	11	$5,995	$6,753	1.1	27.30%
2.2432	Recover Heat From Oven Exhaust / Kilns	318	$41,899	$118,384	1.8	17.80%
2.2433	Recover Heat From Engine Exhausts	16	$27,722	$50,962	2	12.50%
2.2434	Recover Heat From Air Compressor	1,673	$5,509	$4,223	1.1	32.90%
2.2435	Recover Heat From Compressed Air Dryers	15	$25,452	$33,279	1.4	23.10%
2.2436	Recover Heat From Refrigeration Condensers	132	$28,066	$47,987	2	22.00%
2.2437	Recover Waste Heat From Equipment	918	$30,401	$78,044	1.4	37.50%
2.2441	Preheat Boiler Makeup Water With Waste Process Heat	138	$44,079	$23,233	1.4	30.10%
2.2442	Preheat Combustion Air With Waste Heat	209	$50,460	$45,127	1.6	25.30%
2.2443	Re-Use Or Recycle Hot Or Cold Process Exhaust Air	288	$21,519	$39,510	1.7	28.60%
2.2444	Use Hot Process Fluids To Preheat Incoming Process Fluids	198	$36,118	$47,456	1.5	32.70%
2.2445	Recover Heat From Exhausted Steam	59	$79,937	$45,398	1.1	29.80%
2.2446	Recover Heat From Hot Waste Water	136	$28,349	$29,663	1.3	28.70%
2.2447	Heat Water With Exhaust Heat	98	$40,621	$22,301	1.7	31.50%
2.2491	Use Cooling Air Which Cools Hot Work Pieces For Space Heating	34	$6,771	$9,804	1.6	21.90%
2.2492	Use "Heat Wheel" Or Other Heat Exchanger To Cross-Exchange Building Exhaust Air With Make-Up Air	90	$26,889	$51,529	2.5	16.70%
2.2494	Recover Heat In Domestic Hot Water Going To Drain	14	$10,219	$13,794	1.8	28.60%

– Source https://iac.university/topTens

Appendix II Manufacturing SICs

20 FOOD AND KINDRED PRODUCTS
201 Meat Products
202 Dairy Products
203 Preserved Fruits and Vegetables
204 Grain Mill Products
205 Bakery Products
206 Sugar and Confectionery Products
207 Fats and Oils
208 Beverages
209 Miscellaneous Food and Kindred Products

21 TOBACCO PRODUCTS
211 Cigarettes
212 Cigars
213 Chewing and Smoking Tobacco
214 Tobacco Stemming and Redrying

22 TEXTILE MILL PRODUCTS
221 Broadwoven Fabric Mills, Cotton
222 Broadwoven Fabric Mills, Manmade
223 Broadwoven Fabric Mills, Wool
224 Narrow Fabric Mills
225 Knitting Mills
226 Textile Finishing, Except Wool
227 Carpets and Rugs
228 Yarn and Thread Mills
229 Miscellaneous Textile Goods

23 APPAREL AND OTHER TEXTILE PRODUCTS
231 Men's and Boys' Suits and Coats
232 Men's and Boys' Furnishings
233 Women's and Misses' Outerwear
234 Women's and Children's Undergarments
235 Hats, Caps, and Millinery
236 Girls' and Children's Outerwear
237 Fur Goods
238 Miscellaneous Apparel and Accessories
239 Miscellaneous Fabricated Textile Products

24 LUMBER AND WOOD PRODUCTS
241 Logging
242 Sawmills and Planing Mills
243 Millwork, Plywood, and Structural Members
244 Wood Containers
245 Wood Buildings and Mobile Homes
249 Miscellaneous Wood Products

25 FURNITURE AND FIXTURES
251 Household Furniture
252 Office Furniture
253 Public Building and Related Furniture
254 Partitions and Fixtures
259 Miscellaneous Furniture and Fixtures

26 PAPER AND ALLIED PRODUCTS
261 Pulp Mills
262 Paper Mills
263 Paperboard Mills
265 Paperboard Containers and Boxes
267 Miscellaneous Converted Paper Products

27 PRINTING AND PUBLISHING
271 Newspapers
272 Periodicals
273 Books
274 Miscellaneous Publishing
275 Commercial Printing
276 Manifold Business Forms
277 Greeting Cards
278 Blankbooks and Bookbinding
279 Printing Trade Services

28 CHEMICALS AND ALLIED PRODUCTS
281 Industrial Inorganic Chemicals
282 Plastics Materials and Synthetics
283 Drugs
284 Soap, Cleaners, and Toilet Goods
285 Paints and Allied Products
286 Industrial Organic Chemicals
287 Agricultural Chemicals
289 Miscellaneous Chemical Products

29 PETROLEUM AND COAL PRODUCTS
291 Petroleum Refining
295 Asphalt Paving and Roofing Materials
299 Miscellaneous Petroleum and Coal Products

30 RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS

301 Tires and Inner Tubes
302 Rubber and Plastics Footwear
305 Hose and Belting and Gaskets and Packing
306 Fabricated Rubber Products, NEC
308 Misc. Plastic Products, NEC

31 LEATHER AND LEATHER PRODUCTS

311 Leather Tanning and Finishing
313 Footwear Cut Stock
314 Footwear, Except Rubber
315 Leather Gloves and Mittens
316 Luggage
317 Handbags and Personal Leather Goods
319 Leather Goods, NEC

32 STONE, CLAY, GLASS, AND CONCRETE PRODUCTS

321 Flat Glass
322 Glass and Glassware, Pressed or Blown
323 Products of Purchased Glass
324 Cement, Hydraulic
325 Structural Clay Products
326 Pottery and Related Products
327 Concrete, Gypsum, and Plaster Products
328 Cut Stone and Stone Products
329 Miscellaneous Nonmetallic Mineral Products

33 PRIMARY METAL INDUSTRIES

331 Blast Furnace and Basic Steel Products
332 Iron and Steel Foundries
333 Primary Nonferrous Metals
334 Secondary Nonferrous Metals
335 Nonferrous Rolling and Drawing
336 Nonferrous Foundries (Castings)
339 Miscellaneous Primary Metal Products

34 FABRICATED METAL PRODUCTS

341 Metal Cans and Shipping Containers
342 Cutlery, Hand Tools, and Hardware
343 Plumbing and Heating, Except Electric
344 Fabricated Structural Metal Products
345 Screw Machine Products, Bolts, Etc.
346 Metal Forgings and Stampings
347 Metal Services, NEC
348 Ordnance and Accessories, NEC
349 Miscellaneous Fabricated Metal Products

35 INDUSTRIAL MACHINERY AND EQUIPMENT

351 Engines and Turbines
352 Farm and Garden Machinery
353 Construction and Related Machinery
354 Metalworking Machinery
355 Special Industry Machinery
356 General Industrial Machinery
357 Computer and Office Equipment
358 Refrigeration and Service Machinery
359 Industrial Machinery, NEC

36 ELECTRONIC AND OTHER ELECTRIC EQUIPMENT

361 Electric Distribution Equipment
362 Electrical Industrial Apparatus
363 Household Appliances
364 Electric Lighting and Wiring Equipment
365 Household Audio and Video Equipment
366 Communications Equipment
367 Electronic Components and Accessories
369 Misc. Electrical Equipment and Supplies

37 TRANSPORTATION EQUIPMENT

371 Motor Vehicles and Equipment
372 Aircraft and Parts
373 Ship and Boat Building and Repairing
374 Railroad Equipment
375 Motorcycles, Bicycles, and Parts
376 Guided Missiles, Space Vehicles, Parts
379 Miscellaneous Transportation Equipment

38 INSTRUMENTS AND RELATED PRODUCTS

381 Search and Navigation Equipment
382 Measuring and Controlling Devices
384 Medical Instruments and Supplies
385 Ophthalmic Goods
386 Photographic Equipment and Supplies
387 Watches, Clocks, Watchcases, and Parts

39 MISCELLANEOUS MANUFACTURING INDUSTRIES

391 Jewelry, Silverware, and Plated Ware
393 Musical Instruments
394 Toys and Sporting Goods
395 Pens, Pencils, Office, and Art Supplies
396 Costume Jewelry and Notions
399 Miscellaneous Manufactures

Appendix III. IAC Heat Recovery Opportunity Analysis

Download IAC database on from https://iac.university/#database

IAC_Database 3-15-16.xls

File contains 17,280 assessments and 131,014 recommendations.

Delete extraneous columns of data to create:

IAC_Database 3-15-16 Heat Recovery ARC and SIC.xls

Copy "Assessment" tab to new file:

IAC_Database 3-15-16 Heat Recovery ARC and SIC Assess tab only.xls

Copy all 6,468 ARC coded assessments in range 2.400-2.499 from the five "recommendation" tabs, and compile into single tab in file:

IAC_Database 3-15-16 Heat Recovery ARC and SIC REC 2.24 only.xls

Create MSAccess databases from the assessment and recommendation files and join them using common assessment ID#'s, maintaining all recommendations (6,468) and duplicating ID and SIC as needed. Export to:

ASSESSARCJoin 3-15-16.xlsx

Sort by SIC to create:

ASSESSARCJoin Sorted by SIC 3-16-16.xlsx

Sort by ARC Code to create:

ASSESSARCJoin Sorted by ARC code 3-16-16.xlsx

Calculate the frequency of ARC code:

ASSESSARCJoin Sorted by ARC code with frequency 3-16-16.xlsx

Calculate the frequency of 4-digit SIC

ASSESSARCJoin Sorted by SIC with frequency 3-16-16.xlsx

Calculate the frequency of 3-digit SIC

ASSESSARCJoin Sorted by 3-digit SIC with frequency 3-16-16.xlsx

Join IAC assessment heat recovery recommendations to IAC assessment SICs

IAC_Database Heat Recovery ARC and SIC Assess Join 3-15-16.accdb

IAC assessment SIC frequency analysis of ARC codes 2.2411 and 2.2412

ARC 2.2411 3-18-16.xlsx

ARC 2.2412 3-18-16.xlsx

Download from web:

SIC-to-NAICS-Crosswalk.pdf
US Census 1987_SIC_to_2002_NAICS.xls
SICCodeTable(2and3_digits).pdf

Create:

US Census 1987_SIC_to_2002_NAICS_mfg only3-18-16.xls

Extract from NETS database:

WI_NETS2012mfgonly3-18-16.xlsx

Create:

WI NETS mfg NAICS only 3-18-16.xlsx

Join NETS NAICS to IACS SIC:

WI SIC to NETS NAIC 3-18-16.accdb
SIC to WI NAICS Query 3-18-16.xlsx

Create:

WI NETS MFG by SIC 3-18-16.xlsx

Calculate frequency of IAC heat recovery recommendations

IAC Ntl Recs by 3-SIC Frequency 3-18-16.xlsx

Compare frequency of IAC recommendations with frequency of WI manufacturers:

WI NETS MFG by SIC with IAC Rec Frequency 3-18-16.xlsx

Chart frequency comparison and extract shared IAC and WI SICs with >1%frequency:

SICs over 1 percent for both IAC and WI listed 3-21-16.xlsx
WI NETS MFG by SIC with IAC Rec Frequency charted 3-21-16.xlsx

Calculate and plot the frequency of ARC2 by 3-digit SIC, and the frequency of 4-digit SIC within each 3-digit grouping:

1percent SICs with RECs sorted by SIC 3-21-16.xlsx
Frequency of IAC Recs and WI SICs over 1 percent - figures 3-21-16.docx

Create table of all ARC >1% sorted by SIC and cross-referenced to NAICS:

4-SIC Index with 2002_NAICS 3-23-16.xls