

Opportunities for Energy Efficiency in Hydrocarbon Resin Manufacturing Facilities*

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ABSTRACT

Detailed plant-wide assessment of two hydrocarbon resin manufacturing facilities of Neville Chemical revealed significant opportunities for energy efficiency, and consequently air emissions and green house gas reduction in such facilities. The energy efficiency opportunities (EEOs) in the Anaheim plant, the smaller of the two facilities, could save 27% of the facility's annual electrical energy usage, and 36% of its annual natural gas energy usage. The cost savings is estimated at about 20% of this facility's annual energy costs, with an overall simple payback of 1.6 years. The EEOs identified in the Pittsburgh plant, a much larger facility, could save 9% of the facility's annual electrical energy usage, and 54% of its annual natural gas usage. The total annual energy cost savings would represent about 30% of the facility's annual energy costs with an overall payback of 0.9 year. Significant non-energy benefits including waste reduction and productivity improvement measures were also identified.

Introduction

This paper summarizes the results of a plant-wide assessment of Neville Chemical plants in Anaheim, CA and Pittsburgh, PA. US DOE cosponsored the assessments (Ganji, et al. 2002). It was the specific objective of this project to perform a comprehensive plant-wide assessment of the Anaheim plant of Neville Chemical Company, and apply the methods in an assessment of Neville's much larger facility in Pittsburgh, PA. The plant-wide assessment included the processes, electrical and gas equipment, water consumption and waste issues including air emissions, solid waste, hazardous wastes and sewer, as well as other issues associated with the productivity of the plants. Existing production practices were evaluated against best practice standards, as well as utilization of modern technology to improve energy efficiency, minimize the wastes, and improve productivity.

Resin manufacturing, a segment of the chemical industry, is considered one of the more energy intensive industries in the manufacturing sectors. It has been classified as one of the industries of the future (IOF) by US Department of Energy. Census Bureau and Energy Information Administration (EIA) have compiled information regarding this manufacturing market segment (DOC 1992 and MECS 1997). Table 1 below presents some national statistics and metrics for chemical manufacturing facilities, which produce "Plastic Materials and Resins," NAICS 325211.

* Paper presented in the 2003 ACEEE Summer Study on Energy Efficiency in Industry, NY, July 29-Aug. 1.

Considering the high value of energy cost per shipment (6.9%), identification and implementation of energy efficiency measures can have a significant effect on the economics of this segment of the chemical industry.

Table 1. National Statistics and Metrics of Plastic Material and Resin Manufacturing, NAICS 325211			
Data	Nation-Wide	Reference	Neville Plants (US)
Total Number of Establishments	465	MECS 1997	2
Total Number of Employees	61,200	DOC 1992	380
Payroll (\$1,000)	2,698,000	DOC 1992	NA
Cost of Materials (\$1,000)	19,035,100	DOC 1992	NA
Value Added (\$1,000)	12,598,500	DOC 1992	NA
Net Electricity (Trillion Btu)	56	MECS 1997	0.0057
Natural Gas (Trillion Btu)	241	MECS 1997	0.322
LPG (Trillion Btu)	317	MECS 1997	None
Other Fuels (Trillion Btu)	49	MECS 1997	0.320
Million Btus/Employee	5,933.7	MECS 1997	1,841
Thousand Btus/\$ of Value Add.	25.0	MECS 1997	NA
Thousand Btus/\$ of Value Ship.	10.1	MECS 1997	NA
Energy Cost per Shipment	6.9%	Estimated	N/A

The analyses performed in this detailed assessment were concentrated on the measures that were perceived to have a higher chance for implementation. There were several measures identified in the assessment that the facility personnel did not feel would have much chance to be implemented, so those were not analyzed in detail. However, those will also be discussed in some detail.

Resin Manufacturing Process

Neville Chemical specializes in manufacturing hydrocarbon and coumarone-indene resins. The plants employ two variations of the resin manufacturing process: batch and continuous. In both cases, the reaction is a polymerization, yielding low to moderately high molecular mass products. Batch processing is best suited to the production of smaller quantities of specialty resins. Continuous processing is well suited to produce bulk standard and specialty resins, but requires highly consistent feedstock.

Batch Process

The resin production batch process typically includes the following steps:

- The batch reactor is charged with a petroleum-derived monomer mixture.
- The monomer mixture is heated by steam and/or heat transfer oil (HTO) through a set of coils inside the reactor.
- The reactor is heated until the monomer mixture begins an exothermic polymerization reaction.
- At this point the heating is stopped.
- The reaction temperature is maintained by circulating cooling water (~20 °C) through the heat transfer coil that had been used for steam heating. The time that the reaction is maintained at these conditions depends on the desired final product.

- The batch reactor is vented to relieve pressure.
- After venting, additional low molecular weight compounds are removed or “stripped” from the resin.
- After stripping, the resin is tested for quality and if it meets the specifications then it is either pumped out to an accumulator for flake processing or blended with modifiers before being pumped to a storage tank.

Details of the batch production process are shown in Figure 1.

Continuous Process

The continuous process for production of resins typically includes the following steps:

- A feedstock of petroleum-derived monomer mixture is dried.
- A catalyst is introduced into a reactor, which initiates the polymerization reaction.
- As the mixture moves through the reactor the polymerization reaction propagates. The reactor is jacketed for cooling with a fluid (e.g. methanol/water solution or heat transfer oil, HTO), if required, to control the exothermic reaction.
- After reaction, the polymerization process must be deactivated or terminated. Termination consists of the addition of an agent that serves to convert the remaining acids and derivatives to conveniently disposable oxides.
- The neutralized poly-oil is stripped to propagate the resin and low molecular weight compounds.
- The resin may be blended with oil or other modifiers depending on customer specifications.

Figure 2 shows the flow diagram for a typical continuous resin production process. Some details on resin manufacturing processes can be found in (Midenberg, et al.1997).

Major Energy Consumers and Related Energy Efficiency Opportunities

Major Fossil Fuel Equipment

Consumption of fossil fuels in the form of natural gas, and fuel oil (a by-product of resin production) constitute a major cost in resin manufacturing facilities. In both audited plants, the annual cost of fossil fuels (mostly natural gas) was much higher than the annual electricity cost. Major consumers of fossil fuels and the associated energy efficiency opportunities are:

Steam Boilers – Used to produce steam for heating chemicals in the batch processes, stripping, line heating, etc. Significant energy efficiency opportunities exist in the steam system in these facilities.

Thermal Oil Heaters, Oil Furnaces (Natural Draft and Forced Draft) – Used to produce hot oil for heating chemicals to temperature levels usually not attainable by steam

for both batch and continuous processes. Significant energy efficiency opportunities exist in improving the combustion/heat transfer efficiency in the present systems as well as application of advanced technology thermal oil heaters in these facilities.

Thermal Oxidizers – Used for incinerating volatile organic compounds (VOC) produced in various chemical processes. They can be a simple flare to sophisticated regenerative oxidizers. In such facilities significant energy efficiency opportunities exist for heat recovery from conventional units as well as application of advanced technology thermal oxidizers.

Major Electrical Equipment

Lighting – A wide variety of lighting systems, including fluorescent units, high intensity discharge lamps (HID), etc. are used for indoor and outdoor lighting in these facilities. Significant energy efficiency opportunities exist in using advanced technology lighting and lighting control in these facilities.

Fluid Pumps – Fluid pumps for conveying various liquids (water, products, oils, etc.) are a major user of electricity in these facilities. Significant energy efficiency opportunities including proper sizing, use of variable frequency drives (VFD) to adjust to load modulation, etc. exist in these facilities.

Fans (e.g. cooling tower) and Blowers (e.g. aerator) – Fans and blowers are extensively used in these facilities. Significant energy efficiency opportunities including proper sizing, on/off control, use of variable frequency drives (VFD) to adjust to load modulation, etc. exist in these facilities.

Electric Heating – Electrical heating is used to control the product temperature in tanks, trace heating, etc. Significant savings can be realized if steam heating or thermal oil heating is used in place of electric heating.

Chillers and Cooling Towers – To control the exothermic reaction of resin production, a significant amount of energy is used for cooling through chillers and cooling towers. Consequently there exists a significant potential for energy efficiency (such as control of equipment, use of cooling tower water in place of chilled water, etc.) for chillers and cooling towers in these facilities.

Air Compressors – Compressed air is an essential utility in these facilities, and close to 10% of electrical energy is consumed for air compression. Significant opportunities to improve compressed air systems exist in these facilities.

Other Motor Drives (conveying, mixing, agitation, etc.) – Opportunities for energy efficiency exist in application of various motors drives, including proper sizing of motor to match the load, use of premium efficiency motors, control the usage of motors, application of VFD, etc.

Two pie charts illustrating the percentage of electrical energy and fossil fuel energy usage for various functions at a large resin manufacturing plant are shown in Figures 3 and 4 respectively. Distribution of energy usage in a plant depends on many factors including the production technology, locality and the regulatory environment. As an example, use of natural gas for thermal oxidation of VOC is a major energy usage and cost in California, while it may not constitute a significant cost in some other states. Specific measures recommended in the two detailed assessments are presented in the next section.

Major Opportunities for Cost Saving

Neville Chemical was more interested in energy efficiency opportunities with shorter payback periods (about two years and less), so detailed analyses were performed on these types of projects.

Energy Efficiency – Anaheim Plant

Table 2 shows the measures identified in Anaheim plant along with the annual savings and simple payback periods.

Table 2. Summary of Energy Savings and Costs - Anaheim Plant							
EEO No.	Description	Potential Energy Conserved	Demand Savings (kW)	Potential Savings (\$/yr)	Resource Conserved	Implem. Cost (\$)	Simple Payback (years)
1	Install a Variable Frequency Drive on the Cooling Water Pump	221,408 kWh/yr	26.36	16,994	Electricity	13,660	0.8
2	Use Hot Oil Instead of Electricity for Heating Flaking Accumulator Tank	114,318 kWh/yr -5,573** therms/yr	25.40	7,089	Electricity Natural Gas	6,100	0.9
3	Replace the Existing Thermal Oxidizers with an Energy Efficient Unit	-51,935** kWh/yr 291,794 therms/yr	-3.28**	154,751*	Electricity Natural Gas	264,500	1.7
4	Control the Cooling Tower Fan Motors with a VFD	69,685 kWh/yr	8.35	5,353	Electricity	9,103	1.7
5	Install a Variable Frequency Drive on the HTO Pumps	30,773 kWh/yr	4.16	2,406	Electricity	5,104	2.1
Total Energy Savings	(Electricity)	384,249 kWh/yr					
	(Natural Gas)	286,221 therms/yr					
Total Demand Savings			78.2 kW				
Total Cost Savings				\$186,593/yr			
Total Implementation Cost						\$298,467	
Simple Payback Period							1.6 years

*Includes revenue from potential NO_x credits. **Negative savings denotes increase in consumption

Application of VFD on HTO (heat transfer oil) pumps and cooling tower process pumps (Measures 1 and 5) were recommended to avoid by-pass flow as an expensive

control mechanism. In Measure 2, it is recommended to heat a resin tank with HTO in place of electrical resistance heating. Application of VFD on the cooling tower fan motors (Measure 4) was recommended because the fans are currently running at constant speed irrespective of the weather condition. It was recommended to control the fans speed with cooling tower sump temperature. The major energy saving in this plant can be realized from application of an advanced state of the art regenerative thermal oxidizer to replace two common flare-type thermal oxidizers (Measure 3), resulting in both energy cost savings and air pollution credits.

The above energy efficiency opportunities (EEOs) in the Anaheim plant could save about 27% of the facility's annual electrical energy usage, and 36% of its annual natural gas energy usage. The annual cost savings due to implementation of the above EEOs are estimated at about 20% of the facility's annual energy costs, with an overall simple payback of 1.6 years.

Other major energy efficiency measures that were identified in the Anaheim Plant included:

- Replace the Flare, Fume Burner, and Heat Transfer Oil (HTO) Furnace with a Heat Recovery Thermal Oxidizer-HTO Furnace – This is an alternate solution to Measure 3 of Table 2. Replacing the existing flare and fume burner (thermal oxidizers) and the existing HTO furnace with a single unit that oxidizes both VOC streams, and recovers the waste heat, to heat the plant's hot oil system, can result in significant energy savings, and air emissions reduction. The system will need to be engineered. The estimated payback is 2.4 years. A schematic of such a system is shown in Figure 5.
- Use One of the Existing Thermal Oxidizers to Incinerate Both VOC Streams - This is an alternate solution to Measure 3. This measure includes re-routing the VOC streams so that they may be incinerated in one of the existing thermal oxidizers. The estimated simple payback is 1.3 years.

Energy Efficiency – Pittsburgh Plant

Table 3 shows the measures that were analyzed in detail for the Pittsburgh Plant along with the annual savings and simple payback periods. Again, measures with short payback periods were analyzed in detail.

The energy efficiency opportunities (EEOs) identified in Table 3 for the Pittsburgh plant could save about 9% of the facility's annual electrical energy usage, and 54% of its annual natural gas energy usage. The annual cost savings due to implementation of the indicated measures are estimated at about 30% of the facility's annual energy costs, with an overall simple payback period of 0.9 years.

Measures 1, 4 and 8 are considered regular maintenance type measures that have application in most plants and can be adopted as maintenance policies. Measure 2 recommends turning off some 10 hp coil cooling fan motors that are presently running continuously, but they are needed only when the reactors operate in the cooling mode. Measure 3 recommends turning off a few dust collection blowers when the source of dust, a packaging line, is not operating. Measure 5 recommends installation of a lighting control system to dim high intensity (HID) lamps in the aisles of a large warehouse when occupancy sensors do not detect any operation in the aisles for a pre-set period of time.

Measure 6 identifies significant savings if the plant installs a condensate return system to return steam condensate to the boilers. The cost savings include the fuel savings and savings from chemicals for boiler water treatment, and does not include water and sewer costs, which were insignificant for the plant location. In Measure 7 it is recommended to convert still furnaces (used for oil heating) from natural gas to fuel oil (LX-830), which is a by-product of the plant processes. In Measure 9, it is recommended to use waste heat from the thermal oxidizer (with exhaust temperature of about 770 C) be utilized to preheat the heat transfer oil in a nearby furnace. In Measures 10, 13 and 15, it is recommended to install VFD controllers to adjust the operation of the pumps and blowers to the process load demands. Measure 11 simply recommends replacing T-12 lighting with high efficiency T-8 lighting. In Measure 12 it is recommended to install a cooling tower to supply cooling water to replace single path cooling by well water. The savings are realized through less electric energy usage, and lower annual maintenance cost for de-scaling the heat exchangers. It should be noted that the plant is not paying for fresh water or discharge of clean water. Measure 14 recommends installation of heat recovery heat exchangers downstream of ammonia refrigeration compressors to preheat boiler feed water and reduce natural gas cost.

Other major energy efficiency measures that were identified in the Pittsburgh Plant and have potential for substantial savings included:

- Combine Thermal Oil Heaters - Combining the thermal oil heaters (a.k.a. heat transfer oil furnaces) that are located in close proximity to one another will reduce heat up time for each heater. By combining the units, one hot oil heater will be able to heat up more than one reactor. Significant energy savings will result from eliminating heat-up time and idling heat losses.
- Use Modern Burners and Burner Control for Heat Transfer Oil Furnaces – Using heat transfer oil is an essential part of the process in resin manufacturing. Modern thermal oil heaters with efficiencies in excess of 80% are much more efficient than traditional vertical natural draft fired oil heaters, with efficiencies in 60% to 70% range. But often the energy cost savings alone does not warrant their replacement. A more cost effective measure is to install modern forced draft burners to better control the combustion process in the present vertically fired heaters.
- Combined Heat and Power (CHP, the same as Cogeneration) – Larger resin manufacturing facilities are quite suitable for installation of CHP systems, due of simultaneous needs for thermal and electrical energy. In the plants described in this paper, the ratio of thermal energy usage to electrical energy usage is over ten times (a factor of 11 to 16), making some of these plants with continuous production ideal cases for generation of their own electrical power as well as sale of electrical power to others. It should be noted that the maximum temperature needed for heating at these facilities exceeds 550 F, thus making them more suitable for gas turbine based CHP systems.

Non-Energy Benefits – Emissions Reduction and Productivity Improvement

Non-energy cost effective measures were also identified in this assessment. The major cost saving measure identified in Anaheim was to use oxidation ponds to treat their wastewater, with a projected payback of 2.4 years. The short payback is despite the fact that the plant is charged at a rather low rate for the sewer discharge. The major cost saving measure in the Pittsburgh plant was to automate manual packaging operations in Flaker Belt Lines, with a projected payback of 2.8 years, and a cost saving of close to \$1,400,000.

A major non-energy benefit, associated with all identified energy efficiency measures, is reduction in green house gas and other air emissions due to reduced fossil fuels consumption. The air emissions and the related cost benefits were quantified for the Anaheim plant, but are not included here.

Conclusions

Production of hydrocarbon and coumarone-indene resins, like most other chemical processes is detailed and complicated, and alteration of the process for energy efficiency needs exhaustive research and development that is not in the scope of projects such as the one presented here. However, there are significant energy efficiency opportunities as well as non-energy cost saving opportunities that can be implemented with rather short payback periods. Most of the opportunities are associated with support equipment, such as boilers, thermal oil heaters, thermal oxidizers, motors applications and cooling towers. Optimal use of fuels, combustion control and CHP can also result in significant cost savings in such plants.

Major findings from plant-wide assessment of Neville Chemical plants have been presented. The energy efficiency opportunities in the Anaheim plant, the smaller of the two facilities, could save 27% of the facility's annual electrical energy usage, and 36% of its annual natural gas energy usage. The cost savings is estimated at about 20% of this facility's annual energy costs, with an overall simple payback of 1.6 years. The measures identified in the Pittsburgh plant, could save 9% of the facility's annual electrical energy usage, and 54% of its annual natural gas usage. The total annual energy cost savings would represent about 30% of the facility's annual energy costs with an overall payback of 0.9 year. Significant non-energy benefits including waste reduction and productivity improvement measures were also identified.

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Table 3. Summary of Energy Savings and Costs - Pittsburgh Plant							
EEO No.	Description	Potential Energy Conserved	Demand Savings (kW)	Potential Savings (\$/yr)	Resource Conserved	Implem. Cost (\$)	Simple Payback (years)
1	Repair Steam Leaks and Steam Traps	61,583 gallons/yr	N/A	22,378	Fuel Oil	750	Immed.
2	Turn-Off Air Cooler Fans for Heat Poly Units When Not Needed	118,634 kWh/yr	14.13	6,953	Electricity	0	Immed.
3	Interlock Suction Blowers with Packaging Operation	134,608 kWh/yr	0.0	7,928	Electricity	960	0.1
4	Replace Standard V-Belts with Cog-Type Belts	59,690 kWh/yr	7.11	3,498	Electricity	1,228	0.4
5	Install Bi-Level Lighting Control on HID Lights in Warehouses	104,428 kWh/yr	12.42	6,114	Electricity	3,330	0.5
6	Install Condensate Return System	67,975 therms/yr 207,007 gallons/yr	N/A	133,769	Natural Gas Fuel Oil	100,000	0.7
7	Use LX-830 Fuel in Place of Natural Gas in Furnaces	1,219,911 therms/yr -822,981** gallons/yr	N/A	439,250	Natural Gas Fuel Oil	345,000	0.8
8	Install Higher Efficiency Motors*	162,183 kWh/yr	12.87	9,504	Electricity	8,917	0.9
9	Use the Exhaust Gas from the Thermal Oxidizer for Heating	25,736 therms/yr	N/A	15,956	Natural Gas	15,400	1.0
10	Install Adjustable Speed Drives on HTO Pumps	433,577 kWh/yr	51.62	25,407	Electricity	55,616	2.2
11	Install High Efficiency T8 Fluorescent Lighting	25,801 kWh/yr	4.12	1,512	Electricity	3,420	2.3
12	Install Cooling Tower to Recirculate Plant Process Water	143,345 kWh/yr	17.06	20,400	Electricity	50,050	2.5
13	Install Adjustable Speed Drives on Methanol Pumps	97,568 kWh/yr	5.28	5,717	Electricity	17,413	3.0
14	Recover Waste Heat from Ammonia Refrigeration System to Preheat Boiler Feedwater	34,379 gallons/yr	N/A	13,250	Fuel Oil	44,550	3.4
15	Install Adjustable Speed Drives on Boiler Blowers	97,744 kWh/yr	23.27	5,728	Electricity	20,625	3.6
Total Energy Savings	(Electricity)	1,377,578 kWh/yr					
	(Natural Gas)	1,313,622 therms/yr					
	(Fuel Oil)	-520,012 gallons/yr					
Total Demand Savings			147.9 kW				
Total Cost Savings				\$717,364/yr			
Total Implementation Cost						\$667,259	
Simple Payback Period							0.9 years

* Based on 2 year savings. See EEO for details. **Negative savings denotes increase in consumption

Acknowledgement

The authors would like to thank the US Department of Energy for cosponsoring this project. In particular we would like to thank Robert E. Leach of Oak Ridge National Laboratory who patiently managed the project on behalf of DOE. Also the authors would like to thank the management of Neville Chemical Company who provided the opportunity for this detailed assessment. All BASE Energy, Inc. staff have benefited extensively from the experience at San Francisco State University Industrial Assessment Center (IAC).

Figure 1. Diagram of the Batch Resin Production Process

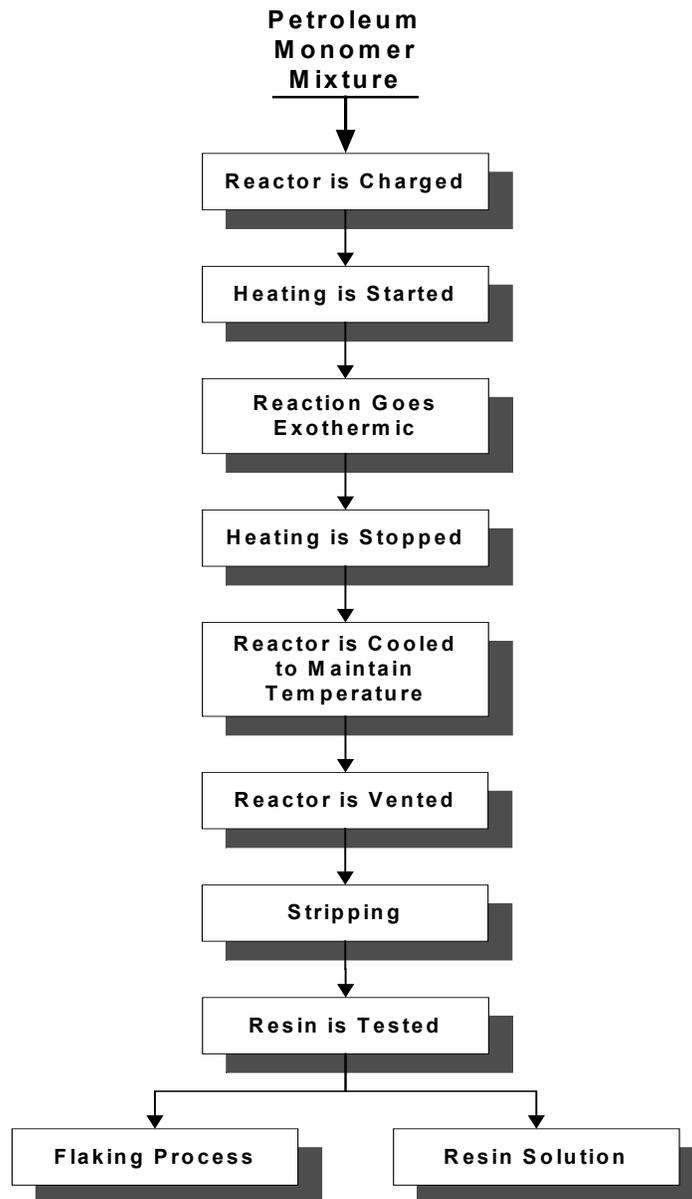


Figure 2. Diagram of the Continuous Resin Production Process

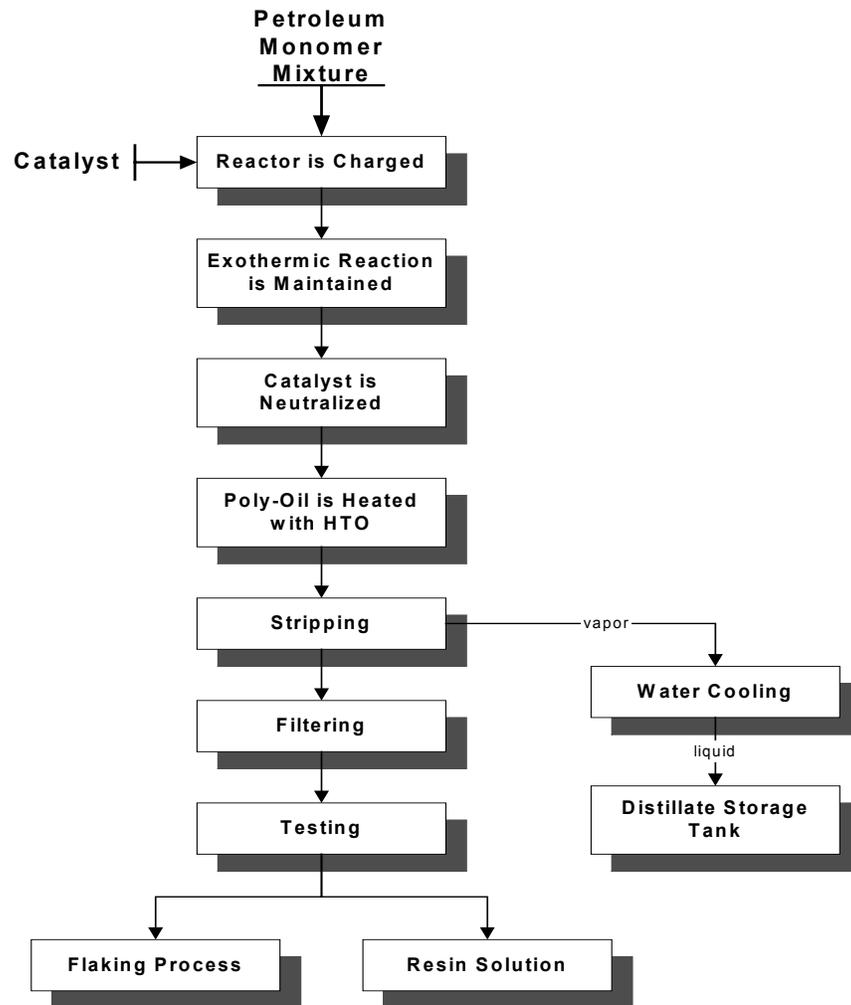


Figure 3. Annual Electrical Energy Usage (kWh) in a Resin Manufacturing Plant

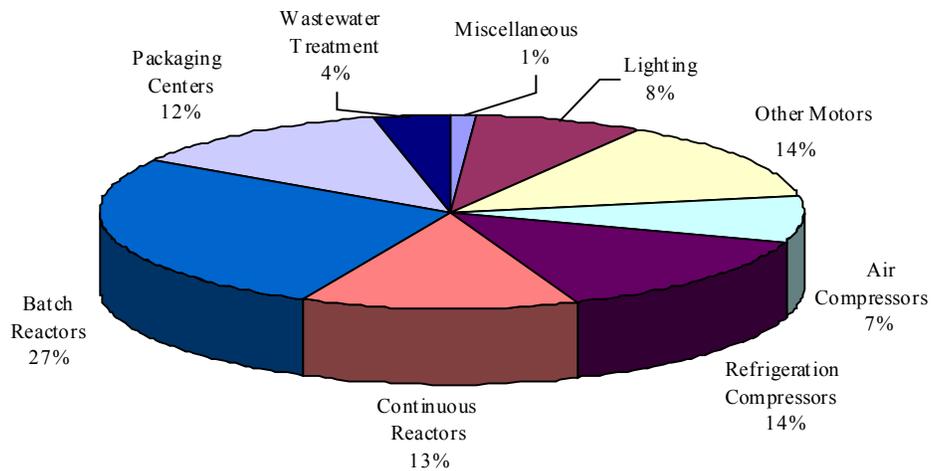


Figure 4. Annual Fossil Fuel Energy Usage Chart in a Resin Manufacturing Plant

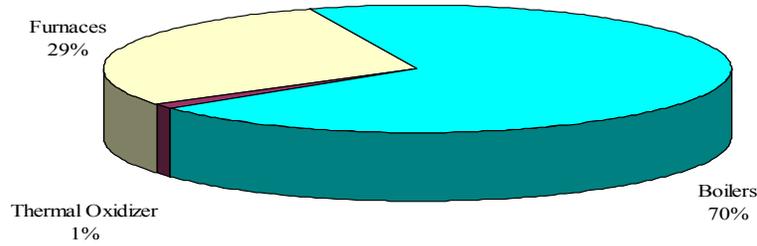


Figure 5. Schematic of Proposed Heat Recovery Thermal Oxidizer-HTO Heating System

