Overview of Rubber industry and rubber product
Rubber Industry and Rubber Products Classification
Specific Energy Consumption and Benchmark
Energy Conservation Promotion Plans
Technology and Energy Conservation Measures
Rubber industry and rubber products are the one of major industry that is significant Thai economy because of it be base industry to make many incomes per year. Moreover, both of the trend of consumption and exportation expand continuously because of the amount of high demand of product usage from rubber industry and rubber products. Then, Rubber industry and rubber products still major industry that the government should testify to encourage and support in order to there has the potential that can compete with the foreign countries in the world market. If consider in the field of energy dimension, rubber industry and rubber products are held to be are the industry that consume energy in the high level and tend to enlarge level of energy consumption depend on the growth of the economy, thus it is necessary to find the way to encourage and support energy consumed efficiently. Unless, affect to the energy saving, still enhances the potential in the competition with the foreign countries in the world market.

In order to achieve the follow objective, Department of Alternative Energy Development and Efficiency originate the project studies standard energy consumption of rubber industry and rubber products by analyses specific energy consumption index of rubber industry which there is many different of energy consumption depending on the products and the production process. In order that, it can be standard energy consumption index of Thailand rubber industry and rubber product which the entrepreneur let this index to compare with others. The other objective, survey for energy consumption status of the industry in the overview including energy conservation assessing, in order to push energy conservation becomes a visible both of in the form of production technology and energy conservation together with high measure of effective energy usage in all format. In order that, the industrial sector of the country has effective energy consumption and topmost efficiency which improves the capability in the competition and the foreign countries and can cope with energy crisis both of situation has in now and the future.

This document invents for the objective in the revelation spreads the result of the project, consist of group of rubber industry and rubber products, standard energy consumption of each sub sector, the way to support and encourage energy conservation in the form of the conspiracy operates short term, medium term and long term including the suitable technology and measure.

Department of Alternative Energy Development and Efficiency
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Rubber industry is considered as an important industry in Thailand based on numbers of employment and exportation. In the term of employment, in 2002 there are 106,844 workers employed in 1518 factories (data from Department of Industrial Works). In the view of exportation, Thailand is the top manufacturer and exporter of natural rubber and its derivatives in the world. In 2006, Thailand produced about 3.03 million ton of para rubber, which was one third of the world production. The main area of para plantation is in the Southern part of Thailand and the remainder is spreading in the Eastern and Northeastern parts. There are 4 types of crude rubber production: smoked sheet, rubber block, crepe, and concentrated latex. From the total production about 90% is exported and the rest is used locally as raw materials for further production for example, tire, shoe, engineering rubber, glove, tread and elastic band. About 80% of finished products are exported except tire that is mainly used domestically in automobile industries. In 2006, exported value of para rubber and related products was about 2.14% of GDP (GDP in 2006 was 7,813 billion Bahts), which was ranked forth among the exporting goods of Thailand as shown in Fig. 1. In addition, 64% of rubber exported was crude rubber (or modified rubber) and another 36% was finished rubber products.

Based on 2006 production, rubber industry production shared about 2.5% of total production of the whole country. The rubber industry can be classified in two groups: middle stream (or crude rubber production) and tail stream production (or finished rubber production). The middle stream mainly produces concentrated latex, rubber block, rubber sheet, and other forms of crude rubber for further finishing processes. The typical products of the tail stream production are tire, glove, automotive parts, and building parts. The tire production is the biggest natural rubber consumer (41.79%) followed by glove production (17.23%).

![Figure 1 The exporting goods of Thailand](image-url)
The future trend of rubber industry

According to the study of the Office of Agricultural Economics, it is found that rubber industry is growing continuously due to the strong demand and the higher production of crude rubber with lower price. However, there is a negative effect of the stronger rate of Thai Baht.

1. Latex production situation

In 2007, latex production is expected to increase about 2.0%. The production at the early of 2007 is 3.09 million ton compared to 3.03 million ton at 2006. The increasing is enhanced by the increases of para plantation and higher demand from the future market and world market.

2. The expansion of the export sector

The crude rubber and its products exportation in 2007 is expected to increase compared to in 2006. The important factors are the expanding economy of the major importers especially USA, China, UN (European Nations) and Japan. Although the economical growth rates of China and USA are decreased compared to last year, the international corporation of rubber exporters has tried to maintain the crude rubber price and to expand the world market.

3. Price of latex

The grand total sell of latex in 2007 is expected to be down from 2006 because of the adjustment of the true demand-supply. In 2006 the latex price was increased abnormally by the fake demand. To prevent the uncontrolled price fluctuation, the future market may be a better choice for latex trading.

4. Foreign exchange rate

For every 1 Baht gain form US $ exchange rate, the export value of rubber will loss 1.50 Baht/kg causing the export decreasing about 12% from the last year, in which the export value was about 200 billion Bahts. Therefore, the government has to control the exchange rate carefully because it affects on economic in both positive and negative ways. However, the export of crude rubber increases 3.9%. If the oil price is still rising, the cost of synthetic rubber will increase and force the manufacturer to use natural rubber more.

5. Marketing opportunity

Due to China preparation for Olympic in 2008, they plan to destroy about 1 million old cars. This will certainly affect to Thailand exporting because of the lost of at least 4 million tires. In fact, China is one of the major crude rubber importer and most of rubber is used in automobile industry.

Overview of Energy Consumption of Rubber Industry

Rubber industry consumes both of the electrical and heat energy. The fuel used for generating heat are gasoline, kerosene, diesel, LPG, heavy oil, natural gas, coal, saw dust, firewood, and rice husk. The type of fuel and technology used are depended on class of industry. The up-stream production, which most work concern the para wood plantation and collecting of latex, consumes small amount of energy. Next step is the transformation of the latex into several forms, for example concentrated latex, rubber sheet, rubber block, and crepe. This step consumes more energy but still small amount. The last step is the real industrial work, in which the natural rubber is changed to finishing products. The three most energy consumption are tire, dipping product, and compressed rubber block. In the tire manufacturing heat from steam is used to heat the mold and calendar and the electricity is supplied to the driving motors. For the rubber block production, most of electrical energy is consumed by the motors while diesel is used to generate heat for the drying oven.
The proportion of energy consumption is presented in Table 1. It should be noted that rubber sheet production uses heat energy in drying step more than 80% of the total energy consumption. While the rubber-block production uses heat energy in the same amount as electrical energy. Totally opposite to the sheet production, the concentrated latex production consumes mainly electrical energy in the centrifugal machines. In tire manufacturing both heat and electrical energy are utilized in the same proportion. The Dipping, Extruding and Forming production consume energy in the different proportion. In dipping process, heat is used most in curing process. In forming process, electrical energy is mainly consumed by the injection molding machines. Extruding process uses both types of energy in the same proportion.

### Energy cost

Not only specific energy consumption (SEC) was determined, but also specific energy cost was analyzed as shown in Table 2. It can be used as an effective tool in the same manner as the SEC but the owner may understand it better than the SEC and can estimate the production cost quicker than using the SEC. In addition, the alternative sources of energy that have the lower price (2007 basis) are also presented.

### Table 2 The result of specific energy cost analysis

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Average energy cost index (Baht/MJ)</th>
<th>Capital index in the case of energy (Baht/MJ)</th>
<th>Benchmark Capital in the case of energy (Baht/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber bar</td>
<td>0.50</td>
<td>1.38</td>
<td>0.94</td>
</tr>
<tr>
<td>Rubber sheet</td>
<td>0.15</td>
<td>0.58</td>
<td>0.35</td>
</tr>
<tr>
<td>Concentrated latex</td>
<td>0.45</td>
<td>0.47</td>
<td>0.32</td>
</tr>
<tr>
<td>Tire products</td>
<td>0.38</td>
<td>7.66</td>
<td>4.77</td>
</tr>
<tr>
<td>Dipping products</td>
<td>0.37</td>
<td>38.82</td>
<td>29.13</td>
</tr>
<tr>
<td>Extruding products</td>
<td>0.45</td>
<td>7.24</td>
<td>3.77</td>
</tr>
<tr>
<td>Forming products</td>
<td>0.44</td>
<td>26.94</td>
<td>11.80</td>
</tr>
<tr>
<td>Miscellaneous products</td>
<td>0.40</td>
<td>7.49</td>
<td>5.09</td>
</tr>
</tbody>
</table>

Noted that *,** represent The result of sample
The Principle of Classification

The whole rubber processing starting from raw materials to finished products can be divided into 4 stages as follows.

1. Preliminary stage

Latex (crude rubber) is produced from rubber tree. Based on energy consumption, this stage may not be classified as industry because it uses very small amount of energy compared with the whole process. It mostly concerns with agricultural work and farmers.

2. Middle stage

In this stage the latex is transformed to desired forms such as concentrated solution, dried sheet, compressed bar before supplying to further production stages. This stage consumes significant amount of energy and must be included in this analysis.

3. Final stage

The raw materials from the previous stage are converted by different processes into finished products. There are a lot of industries both medium and large sizes involve in this stage. They consume large amount of energy as electricity as well as heat.

4. Recycle stage

After used, some parts of rubber products are collected and recycled by proper techniques. The recycled rubber is supplied back as raw material to the production stage. However, there are very few recycling factories in Thailand. The recycling process is often part of production industries in the third stage.

Thus, based on energy consumption this study considered only industries that involve in the middle and final stages. In order to classify the rubber industry and rubber products following steps are carried:

1) Divide the rubber industry into 2 major groups: middle stage and final stage.

2) Identify the key factors that really affect the specific energy consumption (SEC). Finally, 2 factors are chosen for 2 major groups.
   - The key factor for the middle stage is product.
   - The key factor for the final stage is production process.

3) The importance of the population or energy consumption level of each sub-group (sector).

Moreover, the obtained SEC must truly represents each sector and can be used as an effective benchmark. The population of each sector is also considered. If it has too small population, it may be added with other sector
Based on mentioned consideration, the rubber industry and rubber products can be divided into 9 sectors as follows.

### Middle stage
1. Rubber sheet
2. Rubber bar
3. Concentrated latex
4. Synthetic rubber

### Final stage
5. Tire products
6. Dipping products
7. Forming products
8. Extruding products
9. Miscellaneous products

<table>
<thead>
<tr>
<th>Sector No.</th>
<th>Class</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rubber sheet</td>
<td>crude sheet, smoked sheet, natural-dried sheet, oven-dried sheet, band, crepe, skim, skim crepe, skim block, compound rubber</td>
</tr>
<tr>
<td>2</td>
<td>Rubber bar</td>
<td>rubber block, STR rubber, TTR rubber, skim rubber, compound rubber</td>
</tr>
<tr>
<td>3</td>
<td>Concentrated latex</td>
<td>concentrated latex, skim rubber, crepe rubber.</td>
</tr>
<tr>
<td>4</td>
<td>Synthetic rubber</td>
<td>synthetic rubber</td>
</tr>
<tr>
<td>5</td>
<td>Tire products</td>
<td>tire for motorcycle (inner tube and tire), tires for automobiles (passenger car, light truck, and heavy truck), re-tread tire, special tire.</td>
</tr>
<tr>
<td>6</td>
<td>Dipping products</td>
<td>glove, medical glove, disposal glove, nipple, hot/cold bag, finger cap, water sport outfit, balloon, sporting goods, toys, cap, shoe, bandage, elastic tape</td>
</tr>
<tr>
<td>7</td>
<td>Forming products</td>
<td>sponge, carpet supporter, sandal, shoes, rubber band, connecter, curing envelope rubber, curing tube, curing flap, spoon, belt, lining mat, o-ring, roller, bumper, heavy duty pad, seal, gasket, wheel</td>
</tr>
<tr>
<td>8</td>
<td>Extruding products</td>
<td>yarn, elastic thread, brine hose, hose, trim, pipe, electric cable, refrigerator seal, window/door seal, stair handle, insulator, roller, eraser</td>
</tr>
<tr>
<td>9</td>
<td>Miscellaneous products</td>
<td>chemical added rubber, compound rubber</td>
</tr>
</tbody>
</table>
Rubber sheet

Typical products:


Figure 1  Sample of rubber sheet products

Process

The process of making rubber sheet can be divided into following steps:

1. Filter the impurities out of the latex
2. Add acid (formic acid or acetic acid) to solidify the latex. 90% formic acid is widely used because of its superior property.
3. Stir the mixture solution to eliminate the bubble inside. The occurring foam on the surface must be swept out and can be sold as good quality waste.
4. Knead the solidified rubber sheet to have about 1 cm thickness.
5. Press the sheet to 3-4 mm thick
6. Clean the sheet
7. Dry indoor at room temperature to get unsmoked sheet (USS). If further dry by a hot air oven at 45-65 degree Celsius for 3-5 days, a dried sheet will be get. If further smoke at 50-60 degree Celcius for 4-10 days, a smoked sheet will be get.

Energy consumption of rubber production

Smoked-rubber production consumes 2 types of energy.

1. Electrical energy
   Electrical energy is generally used for lighting system and pumping in the process.

2. Fuel energy
   - Firewood is used to generate heat and smoke in the smoking chamber. The most common used is para wood
   - Diesel oil is used for driving motors.

   From the survey of energy consumption of 18 rubber factories, the proportion of electrical energy and heat energy consumption and the proportion of energy consumption are shown in figure 3 and 4, respectively.

   When consider the proportion of electric energy and the heat energy consumption which used to produce rubber sheet in figure 3 it is found that heat energy takes the main proportion more than 80 % of the total energy consumption. The main resource of heat is firewood (most from para wood)
Rubber Industry and Rubber Products Classification

Chapter: 2

Figure 2. The process of making dried and smoked rubber sheet:

1. Filter the impurities out of the latex.
2. Add acid (formic acid or acetic).
3. Solidifiable latex.
4. Press the sheet.
5. Rubber sheet have about 3-4 thickness.
6. Dry indoor at room temperature.
7. Unsmoked Sheet, USS.
8. Dry by a hot air oven at 45-65 degree Celsius for 3-5 days.
10. Check layer by eyesight.

Figure 3. The proportion of electrical energy and heat energy consumption:

- Heat: 83.92%
- Electricity: 16.08%

Figure 4. The proportion of energy consuming under the type of fuel:

- Firewood: 63.92%
- Electricity: 16.08%
- Diesel: 11.33%
- Heavy oil: 6.99%
- Kerosene: 1.68%
Rubber Industry and Rubber Products Classification

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Rubber block

Typical products: rubber block, STR rubber, TTR rubber, skim rubber, compound rubber

Process of STR rubber

There are 2 processes of making STR rubber: from latex and dried rubber. The general procedure is summarized below.

From latex
1. Pretreat the collected latex with sodium sulphite for preserving the latex property.
2. Adjust the rubber content by adding dried rubber. Sodium metabisulphite is used to preserve the color of crude rubber.
3. Add formic acid for coagulation for 12-16 h.
4. Squeeze the coagulated latex to remove the water, then cut into small pieces and wash.
5. Dry at 115-130 degree Celsius for 3-5 h.
6. Weigh the dried rubber of 33.33 kg and then compress to a rubber block.
7. Pack with plastic bag, then store.

From dried sheet
1. Wash rubber sheet with water by a washing machine
2. Squeeze out the water
3. Cut into small pieces by a shredding machine and then clean
4. Dry in an oven
5. After cool down, compress into a block
6. Pack with plastic bag

Energy consumption of rubber block production

The production consumes both of electrical and heat energy. The electrical energy is consumed in milling, compressing and shredding machines. Most of heat energy is used for curing step, in which diesel is burned to generate hot air having temperature about 100 - 120 degree Celsius.

From the surveyed data of 34 rubber factories, the proportion of electric energy and heat energy consumption as well as the proportion of energy consumption based on kind of usage are shown in figure 6 and 7, respectively. It can conclude that electricity is the most used as energy source followed by heavy oil, LPG, diesel, gasoline, respectively.
Figure 5  Process of STR rubber

Figure 6  The proportion of electrical energy and heat energy consumption

Figure 7  The proportion of energy consuming under the type of fuel
Concentrated Latex

Typical products

Typical products: concentrated latex, skim rubber, crepe rubber.

Process of concentrated latex production

Normally, the crude latex consists of 25-45% of rubber content. The remains are water and solid impurities that may affect the rubber quality. Concentrated latex contains rubber content about 60% (dried weight), which is suitable for further processes.

1. The crude latex is collected from farmers and it is pretreated by adding ammonia or ZnO/TMTD.
2. Add some chemicals to adjust its properties.
3. Centrifuge the latex solution to increase its concentration to about 60% and add ammonia (secondary preservation). The obtained latex are HA latex (high ammonia latex) and LA latex (low ammonia latex).
4. Pack into 200 liter tank or bag for further processes.

The skim latex (dilute concentration) is removed the ammonia to be below 2% before adding H₂SO₄ to start the coagulation of rubber mass. Then it is cut into small pieces, dried, and compressed into a block.

Process of crepe rubber and bleached rubber productions

1. Preserve the crude latex with sodium sulphite
2. Adjust the rubber content and add sodium metabisulphite for preventing browning reaction
3. Add bleaching chemicals
4. Add formic acid to coagulate rubber within 12-16 hours
5. Squeeze the coagulated rubber 18-20 times until it is 1.12 mm thick.
6. Cure at 35-45 degree Celsius for 4-5 days
7. Compress to be a block of 33.33 kg and classify the quality
8. Wrap with plastic and store for transportation.

Crepe rubber is a raw material for making variety of products, for example, glue, shoe sole, bottle cap, and bandage.

Figure 8 Centrifugal machine

Figure 9 Process of Concentrated latex and skim rubber
Energy consumption in concentrated latex production

The concentrated latex production is a simply one step process that is the separation of water from the rubber. It consumes only electricity. The main equipment is centrifugal machine with high speed induction motor that consume more than 90% of energy usage. The other machines are water pump, electric fan, stirrer, and equipment in waste water treatment.

Another major consumable resource is water. Generally, concentrated latex factory consumes water about 3-3.5 m³/ton of concentrated latex for dilution and cleaning. For the factories that produce skim rubber block, they need heat energy for curing. Most of them use diesel as a heating source.

From the energy consumption survey of 31 factories, the proportion of electrical energy and heat energy consumption and the proportion of energy usage are shown in figure 10 and 11, respectively. The main source of the energy used in the sheet rubber process is firewood that is used to generate hot air and the rest are electricity, LPG, and diesel.

![Figure 10: The proportion of electrical energy and heat energy consumption](image1)

![Figure 11: The proportion of energy consuming under the type of fuel](image2)

The synthetic rubber

Synthetic rubber is a kind of material that has properties similar to natural rubber. It is designed to have high resistance to solvents, chemicals, and heat with longer lifetime. However, it has low elasticity. Mostly, it is mixed with natural rubber for making better quality products. There are several types of synthetic rubber described as follows:

**Typical products:**

**Styrene-butadiene rubber**

Styrene-butadiene is synthetic rubber that is widely used in USA. It contains 78% of butadiene, 22% of styrene and may be mixed at 40 degree Fahrenheit. This condition, it has special property than natural rubber, used to produce tire. It is high abrasion resistance. Severe weathering, insulated. It is poor weathering at outdoor, wind, ozone, gasoline, and oil may be damage. It is used to product rubber tube, insulate, belt, packaging.

**Polysulfide rubber**

Polysulfide rubber (thiokol or koroseal) is a synthetic polymer made by the reaction of sodium polysulfide with an organic dichloride; resistant to light, oxygen, oils, and solvents; impermeable to gases; poor tensile strength and abrasion resistance. It can be used to make gasket, seal, gasoline hose, and insulator for electrical cable.
**Ethyylene-propylene rubber, EPR**

Ethyylene-propylene rubber, EPR is a copolymer of ethylene and isopropylene. It has light weight and is widely used as an insulator for high voltage cables. It has improved thermal characteristics over more traditional cables, such as cross-linked polyethylene, enabling a smaller cross sectional area for the same load carrying capacity. Its cable is flexible and suited to applications where regular cable movement is required such as in the mining industry and for temporary installations.

**Fluoro rubber**

Fluoro rubber is made by reaction between butyric alcohol and acrylic acid. It has excellent resistance to fuel oil, acid and chemicals. When mix with bromine it has good resistance to gas penetration and radiation.

**Nitrile rubber**

Nitrile rubber or Buna-N, is a synthetic rubber copolymer of acrylonitrile (ACN) and butadiene. Some trade names are: Nipol, Krynac and Europrene. Acrylonitrile butadiene rubber (NBR) is a family of unsaturated copolymers of 2-propenenitrile and various butadiene monomers (1,2-butadiene and 1,3-butadiene). Although its physical and chemical properties vary depending on the polymer's composition of acrylonitrile (the more acrylonitrile within the polymer, the higher the resistance to oils but the lower the flexibility of the material), this form of synthetic rubber is generally resistant to oil, fuel, and other chemicals. Its resilience makes NBR the perfect material for disposable lab, cleaning, and examination gloves. In the automotive industry, it is used to make fuel and oil handling hoses, seals and grommets. NBR's ability to withstand a range of temperatures from -40 to 120 degree Celsius makes it an ideal material for extreme automotive applications. Acrylonitrile butadiene is also used to create molded goods, footwear, adhesives, sealants, sponge expanded foams and floor mats. Compared to natural rubber, nitrile rubber is more resistant to oils and acids, but has inferior strength and flexibility. Nonetheless, nitrile gloves are three times more puncture-resistant than rubber gloves. Nitrile rubber is generally resistant to aliphatic hydrocarbons. However (like natural rubber), it can be attacked by ozone, aromatic hydrocarbons, ketones, esters and aldehydes.

**Polychloroprene rubber**

Polychloroprene is better known to the public as Neoprene, the trade name DuPont gave it when the company first developed it and currently used by DuPont Performance Elastomers. Its monomer is chloroprene that is the common name for the organic compound 2-chloro-1,3-butadiene. This synthetic rubber has structure and mechanical properties like natural rubber. It has high resistance to petroleum solvents, ozone, sunlight, and scratch. It is widely used as gasket, glove, fire-retardant fabric, binder, hose, belt, and electrical insulator.

**Butyl rubber**

Butyl rubber also known as polyisobutylene and PIB (C₄H₈)n is a synthetic rubber, a homopolymer of 2-methyl-1-propene. Polyisobutylene is produced by polymerization of about 98% of isobutylene with about 2% of isoprene. Structurally, polyisobutylene resembles polypropylene, having two methyl groups substituted on every other carbon atom. It has excellent impermeability, and the long polyisobutylene segments of its polymer chains give it good flex properties. Polyisobutylene is a colorless to light yellow viscoelastic material. It is generally odorless and tasteless, though it may exhibit a slight characteristic odor.
Polyurethane rubber

Polyurethane, commonly abbreviated PU, is formed by reacting a monomer containing at least two isocyanate functional groups with another monomer containing at least two alcohol groups in the presence of a catalyst. Polyurethane formulations cover an extremely wide range of stiffness, hardness, and densities. These materials include:

- low density flexible foam used in upholstery and bedding,
- low density rigid foam used for thermal insulation and e.g. automobile dashboards,
- soft solid elastomers used for gel pads and print rollers, and
- hard solid plastics used as electronic instrument bezels and structural parts.

Polyurethanes are widely used in high resiliency flexible foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires, electrical potting compounds, high performance adhesives and sealants, Spandex fibres, seals, gaskets, carpet underlay, and hard plastic parts.

Silicone rubber

Silicone rubber is a polymer that has a "backbone" of silicon-oxygen linkages, the same bond that is found in quartz, glass and sand. Normally, heat is required to vulcanize (set) the silicone rubber; this is normally carried out in a two stage process at the point of manufacture into the desired shape, and then in a prolonged post-cure process. It can also be injection molded. Silicone rubber offers excellent resistance to extreme temperatures, being able to operate normally from -55 to +300 degree Celsius. In such conditions the tensile strength, elongation, tear strength and compression set can be far superior to conventional rubbers.

Compared to other organic rubbers, Silicone rubber has a lower tensile strength. Silicone rubber is a highly inert material and does not react with most chemicals. Due to its inertness, it is used in many medical applications and in medical implants. Silicone rubber also offers excellent electrical/insulation properties.

From the survey, there are very few synthetic rubber industries in Thailand. Therefore, the energy consumption of this sector is very small part and most of energy used is electricity.

Rubber tire

Typical products

Typical products: tire for motorcycle (inner tube and tire), tires for automobiles (passenger car, light truck, and heavy truck), re-tread tire, special tire.

Process of tire production

The tire manufacturing processes consist of 4 main steps:

1. preparing intermediate products (members) utilizing the fluidity and plasticity of crude rubber
2. laminating the members covered with crude rubber utilizing the tackiness of the covering crude rubber
3. assembling the members to make raw tires, and
4. vulcanizing them at the final stage to produce chemically stable and elastic tires.
Energy consumption of Tire manufacturing

Since green rubber is unexpectedly stiff, it is generally sheeted or extruded with a large-capacity motor after it has been softened by heating. The tire manufacturing industry is therefore classified as a large energy consuming industry. The process of vulcanization consumes more steam than any other processes for making tires. Since fuel consumption of the factory is greatly influenced by this process, it is very important to think up how to save energy for this process, which usually accounts for 60 to 90% of the total steam consumption of the fact.

Fig. 15 and 16 show the distribution of energy consumption from 25 tire manufacturers. The sources of energy used in this sector are electricity, natural gas, diesel, steam, and heavy oil.

**Figure 15** The proportion of electrical energy and heat energy consumption

**Figure 16** The proportion of energy consuming under the type of fuel

Dipping Products

**Typical products**

Typical products: glove, medical glove, disposal glove, nipple, hot/cold bag, finger cap, water sport outfit, balloon, sporting goods, toys, cap, shoe, bandage, elastic tape

**Process of dipping production**

Forming production process is product forming by dipping method such as rubber glove, the following chart is an illustration of the dipping process. This method, former is dipped in solvent that slight film forming around former, then dip in chemical, vulcanizing at 120 degree Celsius 30 minute, breading, leaching, coat powder, curing repeat, finally stripping.
Energy consumption in dipping process

Because of tire manufacturing have many products, then would to shown some product that is rubber glove. Rubber glove production process consumed both of electricity and heat energy that generate from fuel source. Most of electricity energy used in the stage of dipping, next air compressor, pump, chiller, vulcanizing and curing, respectively. Most of heat energy is used in curing process.

A survey of 29 rubber factories, the proportion of electric and heat energy consumption and the proportion of energy consuming under the type of fuel are follow as Fig. 19 and 20, respectively. Fuels used in forming production process are electricity, biomass, natural gas, LPG, diesel and heavy oil.
Forming products

Typical products

Typical products: sponge, carpet supporter, sandal, shoes, rubber band, connecter, curing envelope rubber, curing tube, curing flap, spoon, belt, lining mat, o-ring, roller, bumper, heavy duty pad, seal, gasket, wheel

Process of forming production

The main process start from calendering rubber block with heat enhancement and compressing into closed mold, the cavity inside the mold have figure same to product, now known as mold.
Energy consumption in forming production

Because of tire manufacturing have many products, then would to shown some product that is automobile, mainly consumed energy and lightly to generate steam for receive heat energy. Compounding has procedure like to other production process also, such as Kneader machine and two-roller mixing machine. Under the stage of production forming usually compress by mold that electricity used to drive hydraulic motor, heater, office department, pump cooling tower etc.

Figure 23  Flow chart of energy consumption of forming process

A survey of 35 rubber factories, the proportion of electric and heat energy consuming and the proportion of energy consuming under the type of fuel are follow as Fig. 24 and 25, respectively.

Figure 24  The proportion of electrical energy and heat energy consumption

The sources of energy used in this sector are electricity, benzene, natural gas, diesel, LPG, and heavy oil.

Figure 25  The proportion of energy consuming under the type of fuel
Extruding product

Typical products

Typical products: yarn, elastic thread, brine hose, hose, trim, pipe, electric cable, refrigerator seal, window/door seal, stair handle, insulator, roller, eraser.

Figure 26 Extruding products

Process of extruding production

It is one type of forming production process that dry rubber is milled through mold, now known as dies such as door seal for automobile, rubber band, and so on.

Figure 27 Extruding process

Energy consumption in extruding process

Both of the electricity and heat energy is used in production process. The electric energy has to use in every the step, the step that use most of energy is screw, mixing and compressing machine respectively. Heat energy uses in curing process.

A survey of 17 rubber factories, the proportion of electric and heat energy consuming and the proportion of energy consuming under the type of fuel are follow as Fig. 28 and 29, respectively. Fuels used in forming process are electricity, LPG, diesel and heavy oil.

Figure 28 The proportion of electrical energy and heat energy consumption
Miscellaneous rubber products

Energy consumption

Rubber products from other procedure for example chemical added rubber, compound rubber which is product that use in the next step. Thus, most of energy consuming is electric energy, which use in mixing, mill machine and belt. A survey of 11 rubber factories, the proportion of electric and heat energy consuming and the proportion of energy consuming under the type of fuel are follow as Fig. 30 and 31, respectively.

Figure 29 The proportion of energy consuming under the type of fuel

Figure 30 The proportion of electrical energy and heat energy consumption

Figure 31 The proportion of energy consuming under the type of fuel
Specific Energy Consumption and Benchmark

SEC is the ratio of energy consumption quantity and the factor that affects the energy consumption. This factor has many kinds and the difference depends on the activity ties that have energy consumption. SEC be valuable varied for example,

- use to compare the energy consumption in the past with present energy consumption of that factory.
- use to compare the efficiency of the energy consumption of the same type of factory which have energy activities.
- use to assess energy saving of the equipment or the machine that set up for the purpose of energy saving.
- use to compare basic energy saving potential of the equipment or the machine from many suppliers for customer decision making.

The principle of Specific Energy Consumption

Specific Energy Consumption, SEC

After consider the type of fuel that entrepreneur used it is found that there are a number of different type of fuel and the units used for collecting data are also different. In order to compare its index, the unit of energy is converted into “Mega Joule” multiplying by heat capacity value (Heating Value, kJ/kg, kJ/liter, etc.) quantity of fuel. Heating value may be from entrepreneur data or from table 1. (Database of DEDE). As the result of this project it is found that the unit of product while is suitable for calculating SEC and Benchmark, “weight (kilogram or ton)” is order to be to compare among operators.

Table 1 Type of fuel and Heating value

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Unit</th>
<th>hv (MJ/Unit)</th>
<th>Normal Price* (Bath/Unit)</th>
<th>Cost/hv (Bath/MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>kiloWatt-hour</td>
<td>3.60</td>
<td>3.50</td>
<td>0.97</td>
</tr>
<tr>
<td>Benzene</td>
<td>litre</td>
<td>31.48</td>
<td>29.00</td>
<td>0.92</td>
</tr>
<tr>
<td>Kerosene</td>
<td>litre</td>
<td>34.53</td>
<td>25.00</td>
<td>0.72</td>
</tr>
<tr>
<td>Diesel</td>
<td>litre</td>
<td>36.42</td>
<td>26.00</td>
<td>0.71</td>
</tr>
<tr>
<td>High pressure steam</td>
<td>ton</td>
<td>1,710.00</td>
<td>1,000.00</td>
<td>0.58</td>
</tr>
<tr>
<td>Steam</td>
<td>ton</td>
<td>2,110.00</td>
<td>1,200.00</td>
<td>0.57</td>
</tr>
<tr>
<td>Heavy oil</td>
<td>litre</td>
<td>39.77</td>
<td>17.00</td>
<td>0.43</td>
</tr>
<tr>
<td>LPG</td>
<td>kilogram</td>
<td>50.23</td>
<td>16.00</td>
<td>0.32</td>
</tr>
<tr>
<td>Natural gas</td>
<td>MMbtu</td>
<td>1055.00</td>
<td>280.00</td>
<td>0.27</td>
</tr>
<tr>
<td>Import coal</td>
<td>kilogram</td>
<td>26.37</td>
<td>2.00</td>
<td>0.08</td>
</tr>
<tr>
<td>Sawdust</td>
<td>kilogram</td>
<td>10.88</td>
<td>1.20</td>
<td>0.11</td>
</tr>
<tr>
<td>Firewood</td>
<td>kilogram</td>
<td>15.99</td>
<td>1.00</td>
<td>0.06</td>
</tr>
<tr>
<td>Rice hull</td>
<td>kilogram</td>
<td>14.40</td>
<td>0.80</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Noted that

* Average price in 2007

** Consider the efficiency of the conversion of Electrical energy into heat energy at 45%
Specific Energy Consumption analysis

The specific energy consumption index can be calculated from the following equation:

\[
\text{Specific Energy Consumption Index, } SEC = \frac{\text{Energy Consumption (1)}}{\text{Production quantity (2)}}
\]

By giving:

1. **Energy Consumption**

   is total energy consumption of production process that is considered primary energy. The unit is Mega Joule (MJ)

   \[
   \text{Energy Consumption (MJ)} = \text{Electrical energy used in production process (MJ)} + \text{Heat energy used in production process (MJ)}
   \]

   The calculation of electrical energy value

   \[
   \text{electrical energy (MJ)} = \frac{\text{Unit of electricity consumed} \times \text{heating value per unit}}{\text{Electrical generation efficiency}}
   \]

   \[\text{Noted that, heating value per unit = 3.6 MJ/kWh}\]
   \[\text{Average Electrical generation efficiency = 0.45}\]

   The calculation of Heat energy value of fuel used

   \[
   \text{Heat energy (MJ)} = \text{Fuel used} \times \text{heating value per unit}
   \]

   \[\text{Noted that Heating value per unit of fuel as shown in table 1.}\]

2. **Production**

   is the total production. The result of this project indicated that especially in rubber industry and rubber product, the unit of production should use “weight” for comparison.

   \[
   \text{Production (kg)} = \text{production (unit)} \times \text{production weight per unit (kg/unit)}
   \]

   The way of analysis is the standard form that is widely used and compared.

Energy Capital index analysis

The calculation of Energy cost index is to apply specific energy consumption as calculated commercially by the entrepreneurs so that they can fully understand and use it as a guide to select the cheapest energy resource.

\[
\text{Energy investment index} = \frac{T_{\text{Total energy cost (1)}}}{\text{Production (2)}}
\]
The advantage of this calculation is easy to understand and operators can calculate and compare total energy consumption by themselves, including guide you to select cheapest energy resource that is majority of investment but the disadvantage of index is it depends on energy cost while fluctuates all the time. Therefore, result of SEC and Benchmarking calculation can only compare at one point of time. For reference energy cost used in this report is the average energy cost in 2007 as show in table 1

### Benchmarking analysis

The way to calculate benchmark is the principle of good practice that regard to make a confident for institute government sector or factory whom will regard to apply. In addition, as the result found that it hardly to apply foreign SEC or benchmark index to consider together with Thai index because the energy consumption of sub sector may have a different of rubber industry structure of that country, so Thai benchmarking calculated that define by sub sector, as follow

1. Divide the data samples into 3 groups according to their annual production i.e. small, medium and large.
2. Select 20-50 % of the factories which have good energy consumption index or energy capital index in each group, depending on the closeness of the data. The principle of data keeping can be summarized as follow.
   - sort out an sample that are over value from the tendency of the group
   - keep sample that have lower energy consumption index
   - keep an amount of sample enough to find the trend
3. Analysis average value and build a trend by using the data from sample factories which have been chosen to fix the standard value (Benchmark), as shown in Fig. 1 and 2
The result of specific energy consumption index estimated and benchmarking that shows as the graph relation between specific energy consumption index and annual production in the case of energy used and capital by sort of sub sector as shown in Fig. 3 to Fig. 34.
Specific energy consumption index and benchmark of block rubber

Figure 3 The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of block rubber

Figure 4 The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of block rubber
Figure 5 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of block rubber.

Figure 6 The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of block rubber.
Specific energy consumption index and benchmark of rubber sheet

Average energy consumption index
= 3.82 MJ/kg

Average energy consumption index
in the case of capital = 0.58 Baht/kg

Figure 7  The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of sheet rubber

Figure 8  The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of sheet rubber
Figure 9 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of sheet rubber.

Figure 10 The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of sheet rubber.
Specific energy consumption index and benchmark of concentrated latex

Average energy consumption index = 1.05 MJ/kg

Average energy consumption index in the case of capital = 0.47 Baht/kg

Figure 11 The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of concentrated latex

Figure 12 The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of concentrated latex
Specific Energy Consumption and Benchmark

Chapter 3

Figure 13 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of concentrated latex

Figure 14 The graph relation between Benchmark (Baht/kg) and annual production (kg/year) in the case of capital of concentrated latex
Specific energy consumption index and benchmark of tire products

Average energy consumption index
= 19.92 MJ/kg

Figure 15 The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of tire products

Average energy consumption index in the case of capital = 7.66 Baht/kg

Figure 16 The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of tire products
Benchmark in the case of energy consumption = 14.26 MJ/kg

Benchmark in the case of capital = 4.77 Baht/kg

Figure 17 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of tire products

Figure 18 The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of tire products
Specific energy consumption index and benchmark of dipping products

Figure 19  The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of dipping products

Average energy consumption index
= 105.81 MJ/kg

Figure 20  The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of dipping products

Average energy consumption index in the case of capital = 38.82 Baht/kg
Benchmark in the case of energy consumption = 86.77 MJ/kg

Benchmark in the case of capital = 29.13 Baht/kg

Figure 21 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of dipping products

Figure 22 The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of dipping products
Specific energy consumption index and benchmark of extruding products

Figure 23  The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of extruding products

Average energy consumption index = 15.92 MJ/kg

Figure 24  The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of extruding products

Average energy consumption index in the case of capital = 7.24 Baht/kg
Specific Energy Consumption and Benchmark

Chapter : 3

Benchmark in the case of energy consumption = 10.42 MJ/kg

Figure 25  The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of extruding products

Benchmark in the case of capital = 3.77 Baht/kg

Figure 26  The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of extruding products
Specific energy consumption index and benchmark of forming products

Figure 27  The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of forming products

Average energy consumption index
= 61.44 MJ/kg

Figure 28  The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of forming products

Average energy consumption index
in the case of capital = 26.94 Baht/kg
Specific Energy Consumption and Benchmark

Figure 29  The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of forming products

Figure 30  The graph relation between Benchmark (Baht/kg) and annual production (kg/year) in the case of capital of forming products
Specific energy consumption index and benchmark of miscellaneous products

Figure 31 The graph relation between specific energy consumption index (MJ/kg) and annual production (kg/year) in the case of energy used of miscellaneous products

Average energy consumption index = 18.69 MJ/kg

Figure 32 The graph relation between specific energy consumption index (Baht/kg) and annual production (kg/year) in the case of capital of miscellaneous products

Average energy consumption index in the case of capital = 7.49 Baht/kg
Figure 33 The graph relation between Benchmark (MJ/kg) and annual production (kg/year) in the case of energy used of miscellaneous products.

Benchmark in the case of energy consumption = 11.74 MJ/kg

Noted that Hardly to define Benchmark because this sector have various industry.

Figure 34 The graph relation between Benchmark (baht/kg) and annual production (kg/year) in the case of capital of miscellaneous products.

Benchmark in the case of capital = 5.09 Baht/kg

Noted that Hardly to define Benchmark because this sector have various industry.
Specific Energy Consumption and Benchmark

Chapter 3

<table>
<thead>
<tr>
<th>Rubber Sector</th>
<th>Stage</th>
<th>Product Proportion (Material)</th>
<th>Number of Factories</th>
<th>SEC MJ/kg</th>
<th>Benchmark MJ/kg</th>
<th>Delta MJ/kg</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Block</td>
<td>Middle</td>
<td>40.00%</td>
<td>34</td>
<td>34</td>
<td>2.77</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>Sheet</td>
<td>Middle</td>
<td>40.00%</td>
<td>96</td>
<td>18</td>
<td>3.82</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>Concentrated</td>
<td>Middle</td>
<td>20.00%</td>
<td>59</td>
<td>31</td>
<td>1.05</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Tire</td>
<td>Final</td>
<td>50.00%</td>
<td>120</td>
<td>25</td>
<td>19.92</td>
<td>14.26</td>
</tr>
<tr>
<td></td>
<td>Dipping</td>
<td>Final</td>
<td>20.00%</td>
<td>89</td>
<td>29</td>
<td>105.81</td>
<td>86.77</td>
</tr>
<tr>
<td></td>
<td>Extruding</td>
<td>Final</td>
<td>10.00%</td>
<td>59</td>
<td>17</td>
<td>15.92</td>
<td>10.42</td>
</tr>
<tr>
<td></td>
<td>Forming</td>
<td>Final</td>
<td>10.00%</td>
<td>361</td>
<td>35</td>
<td>61.44</td>
<td>36.31</td>
</tr>
<tr>
<td></td>
<td>miscellaneous</td>
<td>Final</td>
<td>10.00%</td>
<td>100</td>
<td>11</td>
<td>18.59</td>
<td>11.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average value</td>
<td>21.78</td>
</tr>
</tbody>
</table>

Table 2 Summarize the result of energy consumption index value and benchmark The result of energy

1. Average SEC is 21.78 MJ/kg
2. Average benchmark is 16.07 MJ/kg
3. Energy conservation potential 32.43%

The comparison of Specific energy

the result of SEC, Benchmarking and Energy Cost per unit analysis can be used for checking or setting goals of energy conservation by the way as follows,

1. Calculate annual production, in weight (Kilogram) as the equation 5.
2. In the case of SEC, calculate annual energy consumption from total energy used such as
   - Energy consumption of office department
   - Energy consumption of raw material preparation and storage
   - Energy consumption of production process
   - Energy consumption of transportation inside factory such as Forklift car
   - Energy consumption of packing
   - Energy consumption of finished goods storing
   Excluding the energy used in the travel and outside factory shipping such as oil tank car or automobile of a factory. After collecting total energy used data, it is converted into heat energy, the unit in Mega joule (MJ) and calculate index value from the equation 1.

3. In the case of Energy cost index, calculate annual energy cost from the same source as in topic 2, the unit in baht, then calculate index value from equation 2

4. compare index value and benchmarking value of each sub sector, as shown below, Fig. 35
For example. A standard comparison of one factory in Extruding industry group

- Annual production that calculated from equation 1 is shown in the X axis (such as, equal to 15 million kilogram / year)
- Index value that calculated from equation 2 or 3 is shown in the Y axis (such as, equal to 6.0 MJ / kilogram)

From the result of comparison it was found that, the index value was slightly higher than the standard (Benchmark), in this case that is about 5.2 MJ/ a kilogram

![Example of standard comparison](image)

**Figure 35 Example of standard comparison**

**The principle of Energy Intensity and Energy Elasticity analysis**

Energy Intensity Indicators is the efficiency indicator index of energy consumption that is widely used and can also be used for assessing the efficiency of energy consumption both of in macro and micro level i.e. industry, sub industry sector, production process and entrepreneur levels. In fact, Energy Intensity Indicators is the ratio of energy consumption and production. The inversion of this ratio is production cost per a unit of energy consumption or energy efficiency and energy productivity.

The change of Energy Intensity also causes the change of energy efficiency and energy productivity of production process. i.e. if energy intensity decreases, energy efficiency and energy productivity will increase. These transition changes can be caused many factors. Analysis will help us to understand the causes of the changes condition. The ratio of energy changed and the production changed is known as Energy Elasticity that indicate characteristic of industry in the case of energy consumption increasing compare with value added. The principle of these index are as below,

\[
\text{Energy Intensity (MJ/baht)} = \frac{\text{Total energy consumption of industrial sector (MJ/year)}}{\text{Total production value of industrial sector (baht/year)}}
\]

\[
\text{Energy Elasticity} = \frac{\text{energy consumption change rate (％)}}{\text{Total production value change rate(％)}}
\]
### The Result of Energy Intensity and Energy Elasticity analysis

Data collected from rubber and rubber product, industries are used to analyze Energy Intensity and Energy Elasticity value as shown in table 3 and Fig. 36 to 38.

#### Table 3 The Result of Energy Intensity and Energy Elasticity analysis

<table>
<thead>
<tr>
<th>Subject / Year</th>
<th>2545</th>
<th>2546</th>
<th>2547</th>
<th>2548</th>
<th>2549</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total products (Thousand ton)</td>
<td>2,632</td>
<td>2,861</td>
<td>3,008</td>
<td>2,980</td>
<td>3,095</td>
<td>2,915</td>
</tr>
<tr>
<td>Energy consumption (x 10^6 MJ)</td>
<td>57,325</td>
<td>62,313</td>
<td>65,514</td>
<td>64,904</td>
<td>67,409</td>
<td>63,493</td>
</tr>
<tr>
<td>GDP of Rubber group (Thousand Million Baht)</td>
<td>131.9</td>
<td>142.11</td>
<td>155.86</td>
<td>152.21</td>
<td>187.63</td>
<td>153.94</td>
</tr>
<tr>
<td>EI (MJ/baht)</td>
<td>0.435</td>
<td>0.438</td>
<td>0.420</td>
<td>0.426</td>
<td>0.359</td>
<td>0.412</td>
</tr>
<tr>
<td>The changes of energy consumption (x 10^6 MJ)</td>
<td>-</td>
<td>4,988</td>
<td>3,202</td>
<td>-610</td>
<td>2,50</td>
<td>-</td>
</tr>
<tr>
<td>Rate of change</td>
<td>-</td>
<td>8.70%</td>
<td>5.14%</td>
<td>-0.93%</td>
<td>3.86%</td>
<td>4.19%</td>
</tr>
<tr>
<td>The changes of GDP (Thousand Million Baht)</td>
<td>-</td>
<td>10.21</td>
<td>13.75</td>
<td>-3.65</td>
<td>35.42</td>
<td>13.93</td>
</tr>
<tr>
<td>Rate of change</td>
<td>-</td>
<td>7.74%</td>
<td>9.68%</td>
<td>-2.34%</td>
<td>23.27%</td>
<td>9.05%</td>
</tr>
<tr>
<td>EE (Ratio)</td>
<td>-</td>
<td>1.124</td>
<td>0.531</td>
<td>0.397</td>
<td>0.166</td>
<td>0.463</td>
</tr>
</tbody>
</table>

#### Energy

![Energy Consumption and GDP Trend](image)

**Figure 36** The trend of energy consumption and GDP since 2002 to 2006
In conclusion, index value of macro level of rubber and rubber product industries calculated from the past five year data has an average value of 0.412 MJ/baht, which is lower than average value of total production of the whole industry. (average value of industry sector is about 0.67 MJ/baht in 2006, Thailand energy consumption data, Energy department) The trend is decreasing every year as shown in Fig. 37 which indicates a better efficiency of energy consumption. For Energy Elasticity the average value is about 0.463 indicates value added rate is more than energy consumption change rate.

Figure 37  The trend of Energy Intensity of rubber industry and rubber product since 2002 to 2006

Figure 38  The trend of Energy Elasticity of rubber industry and rubber product since 2002 to 2006
Summary of Problems and Needs

From entrepreneurs’ questionnaires and experts’ opinions, the problems and needs in rubber industry development are summarized as:

1. lack of unity and continuity from the government,
2. lack of 4Ms, i.e., man (experts), money (investment capital), machine (technology), and management (good management),
3. lack of innovation and know-how to develop new products or to add product’s values,
4. lack of quality control and product standard.

Three strategies are proposed for rubber industry development, i.e.

1. Strengthen the unity and continuous development including
   1.1 establish an organization especially for rubber industry and rubber products,
   1.2 establish a data center especially for rubber industry and rubber products.

2. Increase competitive potential by reducing production costs, increasing production efficiency, adding product values, and establishing product standard including
   2.1 implement energy conservation measures,
   2.2 promote alternative energy sources,
   2.3 establish standard laboratory for quality testing,
   2.4 promote research and development,
   2.5 establish product standards.
3. Human resource in rubber technology by
   3.1 training experts and specialists.

As described above along with energy saving potential in each group, the targets and achievement index of the promotion plans are developed. There are three consecutive plans to promote energy conservation in the rubber industry which are short-term plan (1-2 years), mid-term plan (3-5 years), and long-term plan (> 5 years). The needs of entrepreneurs are considered as first priority in the short-term plan.

### Energy Conservation Promotion Plans

#### The Short-Term Plan

**Project 1.1  Energy Conservation in Rubber Industry**

**Objectives**

1. Reduce production costs by increasing energy usage efficiency to enhance competition capability,
2. Establish an energy expert term in a factory for sustainable energy saving and reducing overall energy consumption in Thailand.

**Approaches**

The government supports energy experts to advise and train staffs to establish an energy team in a factory. The team will be able to analyze energy usage, and specify appropriate basic measures which are approved by DEDE. The implementation plan and saving must be verified by the expert according to IPMVP.

To motivate the entrepreneurs on the investment in selected energy conservation measures (ECMs), the government may provide one of the following incentives.

1. Partial investment in ECMs – DEDE will invest for fixed amount in ECMs such as 50,000 baht or for the proportion of the investment such as 30% of the total investment but not exceed the maximum amount.
2. Tax credit (similar to existing incentive) – saving caused by ECMs can be credited from income tax. DEDE will reimburse such tax approved by energy experts.
3. Loan with low interest rate – banks selected by DEDE will fund ECM projects incorporated with energy experts registered with DEDE.
4. ESCO solution (Energy Service Company) – develop a standard contract between entrepreneurs and equipment suppliers so that they can use as a guideline in their project.

**Project 1.2  Data Center for Rubber Industry**

**Objectives**

1. to establish a data center where information relevant to rubber industry data and rubber products is collected,
2. to establish a communication center between the government and entrepreneurs,
3. to establish an exchange center where successful experiences or good practices are shared among experts and entrepreneurs.
Approaches

The database may consist of
1. production technology based on research and development in Thailand or oversea,
2. energy and environmental technology,
3. good practice in management,
4. projects funded by the government such as training program,
5. up-to-date material prices such as latex, gasoline, coal, diesel, etc.,
6. economic information such as overall rubber products, overall rubber products imported,
7. specific energy consumption (SEC), energy intensity (EI), energy elasticity (EE) analyzed for each sub-sector,
8. publications such as brochure, textbook, etc.,
9. experts and researchers in this field,
10. suppliers and contact information.

The up-to-date data in this database can be accessed by a entrepreneur who registers as a member of the center. The information supplied by entrepreneurs will be used to update the database such as production, energy consumption, etc.

Project 1.3 Promotions of Alternative Energy Resources

Objectives
1. decrease energy cost,
2. enhance production stability,
3. decrease imported crude oil and energy.

Approaches

One of major factors that influence cost of the products is types of fuel used in the production processes. For instance, cost of steam generated from diesel boiler is much greater than wood boiler. The factory may consider an alternative fuel that can be used for production such as natural gas, biogas, bio-diesel, and waste from agricultural processes. Coal is another alternative fuel that can be used; however, exhausted gas must be carefully treated before emitting to the environment. Some of fuel can be used with minor system modification such as replacing fuel oil with NGV.

Co-generation is an alternative system to increase system efficiency. It is suitable for a factory whose process needs both electric and heat. Heat or steam generated by co-generation can be a energy source for a nearby factory. In present, the implementation of micro turbine in a medium enterprise is economically feasible.

The medium-term plan

Project 2.1 Establishment of Standard Test Laboratory

Objectives
1. measure and verify for standard quality of products and raw materials,
2. improve products’ standard,
3. enhance the ability to export products and goods to high standard country such as EU.

Approaches

The laboratory will provide services on testing quality of products and raw materials based on international standards. This is a commercial laboratory fully with equipment, tools, and experienced staff that can provide efficient services and correct test results.
Project 2.2 Promotion of Research and Development

Objectives
1. to change from OEM to manufacturer by researching and developing in-house knowledge and technology,
2. to be able to survive in high competition market based on cost controls and value-added using own innovation and R&D.

Approaches
The government will promote research and development by which research topics are derived from every sector that involves in rubber industry and rubber products and from up-stream to down-stream production. The topic will be categorized based on their impact to the industry. Related topic may be combined to a set of research topic and distributed to researchers in educational institutes. The proposed projects will be funded by the government and manufacturers who needs such technology. The research topics will be organized for efficient use of fund and less redundant topics.

Project 2.3 Human Resource Development

Objectives
To obtain qualified specialists and experts.

Approaches
The government will encourage university and/or college to obtain graduated student in the field of rubber industry or rubber products. The graduated student may earn college certificate, or bachelor degree. A manufacturer or a group of manufactures may provide a conditional fund (students must work for them after graduate), in-turn ship, or bi-educational program (students will work for manufacturers and study at college or university at the same time.)

The long-term plan

Project 3.1 Establishment of a Specific Organization for Rubber Industry and Rubber Products

Objectives
1. to unite activities and events by the government, manufactures, suppliers, and so on, so that redundant activities could be eliminated,
2. to sustain the development in the field.

Approaches
The government is a host to establish an organization that composes of several involved parties. The organization will develop a master plan to lead and target the industry, and accomplish their plan.
- To be the host for developing a master plan and accomplish the plan,
- To be operators and coordinators for parties to promote the industry and provide one-stop service on technologies, funding, and consulting,
- operate the data center previously mentioned.

Project 3.2 Establishment of a Specific Standard for Rubber products

Objectives
1. to improve quality of products,
2. to enhance the ability to compete in the market for export to rival countries, such as Malaysia, Indonesia, Vietnam, and Chinese.

Approaches
Thai Industrial Standards Institute associated with the organization established in 3.1 provides various standards for rubber products and raw materials.
In this chapter, technology and energy conservation measures will be presented for each category.

ECMs in Electric Cost Structure

Electric cost management

There are several structures of electric cost depending on the amount and type of usage. The customer needs to understand the contents and methods to evaluate the monthly electric bill.

Most of manufacturers in rubber industry implement a “Time-of-Use” structure or TOU. TOU is an electric cost structure that encourages users to consume the electricity in the off-peak period. The electric rate in the on-peak period is much higher than one in the off-peak period. The on-peak and off-peak periods are defined by time and day of week.

A monthly electric bill consists of two basic charges, i.e.
1. a charge for the energy consumption,
2. a charge for the peak demand.

It is noted that the utility providers may have an extra charge for customers who consume energy with power factor below 0.85.

There are several measures that can be implemented to reduce electrical energy costs, such as
1. reduce peak demand
2. shift electric loads from on-peak period to off-peak period
3. reduce energy consumption
4. improve power factor

For example, consider a 24 hours electric profile of a factory on a weekday. It shows that base load power is at 200 kW between 6:00 am to 10:00 pm and peak demand is at 900 kW at noon for 1 hour. Such peak demand is because many machines concurrently start-up. To reduce peak demand, the start-up time of each machine can be re-scheduled so that they do not start at the same time. It may be possible to reduce peak demand from 900 kW to 600 kW or 33% saving. In addition, if the electric energy load can be moved from on-peak to off-peak period,
the energy cost will reduce by 56%. By reducing the demand and shifting loads, the amount of consumed energy is still the same, only the cost is reduced. To reduce the energy consumption, other energy conservation measures must be implemented such as energy loss reduction, good-practice of machine operation and machine maintenance, training, etc.

Power factor improvement will reduce losses in distributor system. The power factor is given by

\[
\text{Power Factor} = \frac{\text{kilowatts (resistive power)}}{\text{Kilovolt - amperes (resistive plus reactive)}}
\]

Electric power is a function of resistance and reactance by which the distribution system is effected on. Two electric currents are incurred in the distribution system that is active and reactive current. Active current provides active power supply to loads and reactive current provides reactive power that is not useful to load and causes by inductive or capacitive equipment. The higher the reactive power, the higher the losses in the distribution system. The active power can be increased by reducing the reactive power.

Inductive loads will lower the power factor in the system. The induction loads are such as transformer, arc welding machines, induction heating coils, lighting ballasts, and under loaded AC induction motors.

**Management measures**

1. Examine a load profile to determine energy saving measures to reduce energy consumption and peak demand, and also to improve power factor. Savings from these measures can be used for machine modifications and high efficient machine replacement.

2. Analyze the load profile, especially energy consumption in high energy-consumed machines, and determine measures to reduce peak demand and to shift load shifting. There are several alternative to do so, such as
   2.1 re-schedule operating hour to off-peak period,
   2.2 turn-off minor loads during on-peak period such as supply water pump, air-conditioner, etc.,
   2.3 turn-off equipment and/or machine during break hours such as lighting,
   2.4 shift battery charging period and/or storage water pump to off-peak period.

**Machine/Equipment Improvement Measures**

Where several mixers are used, try to eliminate the least efficient mixer, and plan to use most efficient mixers.

1. Improve accuracy of weighting system to about +/- 0.2% for chemicals, polymers, etc. to reduce off-spec compounds.
2. Install energy and power meter for each mixing machine to record energy consumption for each batch. This data will be used to investigate mixing efficiency, variation, and operating hours to plan best practice for mixing machine.
3. Consider the possibility to reduce mixing cycle by the following techniques
   - Accelerate mixing speed,
   - Accelerate time to mix chemical and compound added in the mid of the cycle,
   - Install a high speed lubricant injection system,
   - Reduce number of ram loading,
   - Increase ram compression force,
   - Increase mixing RPM.
**Machine/Equipment Improvement Measures**

Low power factor is mostly caused by over sizing induction motors. In such case, the power factor could be improved by replacing existing motor with appropriate size of motors or installing capacitor banks at electric panels, by doing so the payback is approximately 18 months.

### ECMs in Mixing Processes

**Management measures**

1. Apply appropriate loads for each mixing batch to reduce mixing cycle, mixing time, and to increase mixing efficiency (kWh/kg),
2. Examine energy consumption in terms of kg/hr and/or kWh/kg for each particular batch, the machine with the lowest consumption should be continuously used,
3. Install temperature sensor, power meter, and data logger at mixing machine to measure mixing temperature and power,
4. Optimize loads and compounds for mixing batch,
5. Optimize mixing stage for each batch,
6. Optimize mixing schedule to reduce downtime,
7. Maintain efficient cooling system in mixing and milling machine to increase heat transfer efficiency,
8. Study and understand machine operation manual from suppliers.

**Machine/Equipment Improvement Measures**

Where several mixers are used, try to eliminate the least efficient mixer, and plan to use most efficient mixers.

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   - Increase ram compression force,
   - Increase mixing RPM.
Technology and Energy Conservation Measures

Chapter : 5

Milling is a process between mixing process and vulcanization process. Consumed energy by milling machine depends on products and type of machine such as milling machine, carlenderring machine, and extruding machine. Tire products consume more energy than injection mold products. The amount of energy consumed during the milling processes is related to one during the vulcanization processes.

**ECMs in Milling Processes**

Milling is a process between mixing process and vulcanization process. Consumed energy by milling machine depends on products and type of machine such as milling machine, carlenderring machine, and extruding machine. Tire products consume more energy than injection mold products. The amount of energy consumed during the milling processes is related to one during the vulcanization processes.

During the last mixing stage, additives are added and the mixed compound is so-called “stock”. The stock is in a plastic state where the compound can be formed to desirable shape till vulcanization. The stock can be formed by passing between rolls (milling and calendering), by passing it through an orifice of the desired shape (extrusion) or by confining it under pressure in a mold of the required dimensions. These operations are usually called processing operations by which the temperature of the stock is rise.

The additives maintain the stock in desirable shape during forming processes at medium temperature before vulcanization during which it is so-called “scorch time”. If total forming time exceeds the scorch time, the stock will scorch. Thus, in general the forming period must be as short as possible to avoid scorching. The duration between forming and vulcanization is so-called “residual scorch time”. The vulcanization period is the sum of the residual scorch time and crosslinking time which is the duration between the start of curing process and the end of curing process. Products with high residual scorch times consume more energy than required and also investment in curing equipment.

Milling process time depends on production rate, forming time, and operators’ experiences. It is noted that high mill bank, an operation where there are residual stocks on the top of milling machine, causes high temperature of stock, long milling time, and energy consuming process. To save energy during the process, the following practices should be done:

1. avoid re-heat and re-cool process of stock,
2. reduce the milling time for each operation,
3. reduce mill temperatures using passive heat transfer,
4. replace hot feed processes with a more energy efficient cold feed extrusion process.

**Machine/Equipment Replacement Measures**

Replace low efficiency mixers with high efficiency mixers.

4. Replace pneumatic system with hydraulic system to move ram and open/close mixing door. The hydraulic system consumes less energy and more accurate.
5. Install a digital controller to control mixing machine to optimize machine performance and save energy.
6. Install variable speed drive in filtering system to optimize air flow rate and pressure drop across the filter.
7. Install variable speed drive at driver of mixing machine to optimize mixing speeds and power according to various mixing loads.

**Figure 5** Carlender
Measures in the forming/milling process can save energy in vulcanization process, such as
1. reduce process variations;
2. reduce re-shaping and re-size of products. Changing hot feed extrusion processes to cold feed extrusion process stock processing can reduce energy consumption in milling processes about 50% and also in vulcanization processes due to less variation in pre-formed stocks.

Management measures
1. Review milling procedures to reduce time and stock variations such as milling techniques, milling banks, etc.
2. Evenly distribute the stock over the calender roll and minimize the amount of stock on the calendar nip to avoid "dead spot" where compounds do not flow through nip.
3. Empty stocks before stopping the machine.
4. Turn-off all auxiliary components when machines not in use such as heating/cooling devices, exhaust fans, cooling pumps, etc.
5. Remove scaling in cooling systems to enhance heat transfer coefficient.
6. Adjust water flow rate of cooling system to meet heat loads of machines by using automatic devices or manual valve adjustment based on water temperature.
7. Utilize most efficient machines instead of worst efficient machines.
8. Utilize water-based adhesives instead of chemical-based adhesives or develop a non-adhesive technique.

Management measures
1. The most effective way to reduce milling temperatures and energy is to reduce the surface speed of the mill roll.
2. Utilize hot air blower instead of compressed air to dry out materials in-process.

Machine/Equipment Replacement Measures
Cold feed extrusion systems consume less energy in the cooling systems than hot feed systems approximately 70%. Moreover, they can improve product quality, reduce scorch, increase productivity, and reduce required space. Utilize of multi-extrusion systems reduces milling procedures. Cold feed extrusion systems should be considered as a replacement for calendaring systems to save energy.
ECMs in Scrap/Waste Management and Product Reworking

An inefficient process produces huge amounts of scrap and waste in which some may be reprocessed; however, energy was already consumed by these scrap and waste. If they are taken into account, the reworking products consume twice or more energy than a regular one. Hence, by reducing waste, not only energy can be saved, but also material and labor costs.

Most of machine operators believe that there are no costs associated with scrap/waste because they can be reused. Unfortunately, that is far from the truth. There are costs associated with them, i.e.

- Energy costs of scrap/waste because they are once flowed through the processing line by which energy is consumed,
- Labor costs due to the segregation, qualification, trucking and storage of the rework material,
- Storage costs for scrap/waste,
- Costs of laboratory test and quality control,
- Handling and transportation costs,
- Quality degradation costs of products due to mixing between waste and raw materials,
- Additional energy costs due to reprocessing. Management and reprocessing costs are greater than 5% of total processing energy costs.

Management measures

1. “Zero waste production” policy – all wastes of wastes must be daily recorded and analyzed to determine caused and solution to reduce wastes.
2. Examine milling processes if scorch compounds are found – mill banks should be less than 150mm in diameter if rolling mill is used, or less than 15mm if calendar nip is used. There should not be residual in the machine if stopped.
3. Production variations – quality assurance and operation control should be implemented, such as Statistical Process Control (SK), by which the variation can be reduced.

Machine/Equipment Improvement Measures

1. Quality assurance for each production procedures – before transferring compounds to adjacent procedures, compounds should be examined if they are qualified. An unqualified compound should be rejected and determined its causes. Mixing ratio of each raw material should be examined if there are problems with accuracy of weighting system or not. Equipment upgrade may be considered.
2. Compound temperature control – continuously examine compound temperature. The high temperature compound may be caused by inefficient cooling system, or high rolling speed.
3. Instrument Calibration – vulcanization process requires precise control of temperature, pressure and time. Instrument and sensor should be calibrated on a regular basis for high reliability and precision.

ECMs for Block Rubber

Waste Heat Recovery from Curing Processes

In the curing stage of block rubber production process, the rubber is heated or cured in ovens, after that the cured rubber is cooled by cooled air. Waste heat removed by the cooled air can be mixed with fresh air and then supplied to the burner to save energy.
Technology and Energy Conservation

Chapter : 5

Optimized Pressure in Hydraulic System of Milling Machines

Most milling machines have hydraulic system installed. The appropriate pressure of the hydraulic system should be used for particular thickness of block rubber to save energy.

Power Transmission System Modification

It is noted that gear driving system consumes less energy than belt driving system. Thus, if applicable, gear driving system should be implemented.

Material Delivery System Modification

If applicable, screw or belt conveyor systems should be implemented instead of pumping system. Size of driving motors in screw or belt system is much less than pumping system, so that consumed energy is less.

ECMs for Latex

Optimization of Speed of Latex Separator

Most energy consumed by latex separator is at motor that drives a rotor. Consumed energy is proportional to the rotor speed. The higher the rotor speed the higher energy is consumed. However, the efficiency of the separator is also proportional to the rotor speed. The higher the rotor speed, the higher the efficiency is. Thus, optimized rotor speed should be investigated to compromise between efficiency and energy.

Separator Mass Reduction

Power needed to rotate the rotor is proportional to mass of the rotor, torque, and speed. In this case, if the mass of the rotor is reduced by 10%, the energy consumed will decrease approximately 10%.

Successful Case Studies

1) Operation of High Efficient Latex Separators

There were several units of latex separator in a factor at different life time. The factory had recorded energy consumed by separators and found that they could be classified into 2 groups; there were 5 units consumed 38 kWh/ton, 10 units consumed 43 kWh/ton. Thus, the first group worked for based production, and the second group worked when additional products required. If production rate is 4 ton per unit in average and 10 separators run 4,000 hour per year. They can save energy by amount of 400,000 kWh/yr or 1,000,000 baht per year ((43-38) kWh/ton x 4 tons x 5 units x 4,000 hr/yr).

2) Reduction of Latex Spinning Period During Property Adjustment Process

To meet latex property standard, some chemicals or solutions are added into the latex. In the process of property adjustment, the latex must be stirred for 40 minutes before and after adding chemicals or solutions. For energy efficient operation, the factory will trial and error to determine the best spinning period where they will get the best latex by which the energy can be saved for 5-10%. In addition, there are several factors that affect spinning efficiency and latex quality, that are shape of spinning storage, shape, profile, and position of propeller, and also rotational speed.
3) **Reduction of Latex Agitating Period in Storage**

The thick latex will be delivered to storages by diaphragm pumps. The capacity of the tank is particularly 100 tons per unit with 10HP agitator. To preserve the latex for future use, additives are added and continuously agitated for 4 hours. After that, they must be stirred every 2 hours to avoid latex forming. In addition, they must be agitated for 1 hour before loading to the truck. It is obvious that this process is a high energy consuming process.

4) **Cleaning of Latex Separator Filters**

Inside latex separator, there are hundreds of filters. The filters are made of stainless steel of conical-like shape. The filters are stacked up on each other. Once separator’s rotor rotates, latex flows through a space between filter to separate latex from water in raw material. Filters must be cleaned every 2-2.5 hours to avoid degradation of separator and save energy by 10-20%.

5) **Rotor Balancing**

The rotor of latex separator rotates at 7200 rpm. If the rotor is not balance, the separator will vibrate and efficiency will decrease due to reduction of thick latex. The vibration of separator will reduce life time of bearing. By balancing rotor, the bear’s life time is prolonged, energy consumption and maintenance costs are reduced.

6) **Demand Management**

Demand charge is a fee in monthly electrical bill and has a great effect on electric costs. Controlling the demand will save such a great amount of electric cost, for example, using of demand controller.

### ECMs for Tire

**Condensate Recover**

Tire manufacturing is one of industries that consumed a large amount of heat, i.e. steam. Steam is indirectly used to cure rubber in a mold to produce tires at specific shape. There is a great amount of condensate from this process. If the condensate can be entirely recovered, they can save a huge amount of energy and expense.

**Insulating Cure Machine and Steam pipe using Flexible Insulation**

During curing process, a mold is continuously heated by steam for a period of time. The mold is not typically insulated because of assembly, moving parts of mold. Thus, mold insulation should be investigated and researched for optimal insulation method to reduce heat losses.

### ECMs for Products by Dipping Processes

**Reduction of Water Temperature in Latex Glove Production**

In the process, mold will be submerged into several tanks of water and solutions. The temperature of these solutions will be automatically controlled and usually over setting by operators. Provide training and operation instruction to operators for appropriate temperature setting will save a great amount of energy.
Controls of Water Flow Rate in Leaching Process

In leaching process, a great amount of water is excessively used to make sure that chemical and solutions are get rid of gloves. The optimum amount of water should be investigated and implemented with the same product quality.

Controls of Compressed Air Flow Rate and Pressure in Stripping Process

Stripping process is a process that uses a great amount of compressed air in such a way that both flow rate and pressure of compressor is much more that its needs. Optimization of flow rate, pressure, and size of orifice will reduce energy consumption of this process.

Improvement of Mold Design and Curing Method

Current mold design requires hot air to heat both molds and their stations of about 80 kg. However, the finished product is about 1 kg. Improvement of mold design to reduce mold capacity will save a great amount of energy.

ECMs for Products by Forming Processes

Control of Cooling Water Temperature

In tire production, the temperature of the cured rubber is usually controlled to a particular value by cooling water. The temperature of the cooling water plays an important role to product quality and energy consumption. The temperature and flow rate of the cooling water should be investigated and research for optimum values.

Separation of Heating and Cooling Circuits in Mold Design

In curing process of a tire production, steam is injected into the mold to heat the preformed rubber. After the rubber is cured, steam valve is closed and then water flows into the mold to cool down the cured tire. Because of existing mold design, the water and steam use the same circuits. By doing so, the condensation of the steam cannot be recovered. For next generation, the design of heating and cooling circuit in molds should be separated.

ECMs for Products by Extruding Processes

Reduction of Additional Lighting for Ionizer

In packaging process of elastic rubber, ionizers are required to reduce static electricity. High voltage transformer of 15kVA is a power source of the ionizers (10 units). Operators found that the ionizers work properly during the day because of high ambient temperature, but not function properly during the night. Thus, they have installed high intensity lighting system (3x1500W) to increase temperature which consumes a great amount of energy. To save energy, additional high voltage transformer should been installed instead of high intensity lighting system because of less energy consumption.

Additional ECMs

Reuse/Recover of Rubber Scrap

During the production process, there are plenty of rubber scraps. These scraps are currently useless for the production and be burnt in high temperature oven in cement factory. There is a need for research and development to reuse and value-added these scrape because exhaust gases from the combustion of scrap pollute the environment.
Continuous Production Process

In rubber production, rubber will be reheated and re-cooled for several times. The production process should be organized in the way that the rubber is continuously processed through high temperature processes at a time and then low temperature processes or vice versa to avoid reheat or re-cool the rubber.

Reduction of Operating Pressure of Steam

Most factories use steams as a heat source and normally over setting operating pressure of steam. Steam should be set to appropriate operating pressure for less energy consumption.

Appropriate Motor Horse Power

Most factories use oversized motor to drive machines in milling, compressing, and conveying system. Appropriate use of motor horse power can save a great amount of energy.

ECMs in Curing/Vulcanization process

Curing is a key process that consumes a great amount of energy in rubber processing. Appropriate use of curing methods, techniques and design are the most efficient way to save energy in curing process. Currently, there are several curing methods as shown below.

Compression Molding

Compound is placed on a mold and pressed to fill up the mold. Then, heat is applied via the mold, not directly at the compound.
**Transfer Molding**

Compound is preheated and feed into the mold through an opener. Preheated compound will be pressed through cavities inside the mold of different shape and then heated. By this method, numbers of finished products can be produced per cycle and curing time is less because the compound is preheated before injected into the mold.

![Transfer Mold Diagram](image1)

**Figure 15** Forming by transfer mold

**Injection Molding**

Preheated compound is extruded by screw extruder into injection ram of different shape. This process is suitable for mass production with high degree of automatic control and high quality.

![Injection Mold Diagram](image2)

**Figure 16** Forming by injection mold

**Steam Autoclaves**

Autoclaves are used to cure large products that are not suitable for conventional molding presses such as large off-road tires, re-treaded tires, large extrusions, hoses, rollers, large moldings, etc. The product inside the autoclave may be heated directly by steam or indirectly by air or inert gas that is heated by steam.

![Steam Autoclave](image3)

**Figure 17** Rubber oven
Belting Presses

Compound is placed on the pre-fabricated belt and driven between two plate heaters. Plates are moved down to press and cure the compound.

Tire Curing Presses

Tire curing process is a type of compression curing. The differences from conventional method are that heat and pressure are applied by rubber bladder that inflates inside the tire. Steam or pressurized hot water is the most commonly used methods for heating the internal and external parts of a tire.

Steam Tube Continuous Vulcanization

Rubber cables, hoses and reinforced rubber products are cured by high pressure steam. Heat is applied step-by-step through the production process from high pressure steam, high pressure hot water, low pressure hot water and then leaving the process. This type of curing is commonly used with an extruder.

Fluidized Bed

This system is typically in use with extruding process that produce profiled strip or cables. The fluidized bed consists of ceramic or glass beads that are held in suspension by jets of hot air or inert gas. Heat is transferred from beads to products by conduction and convection heat transfer. Steam is a typical heat source for the system.
Drum Vulcanization

Drum vulcanizers are normally used to cure rubber-coated sheets and proofed fabrics by heating them on rotating drums. When a consolidating pressure is required, a flexible steel belt is used to apply pressure on the surface of the sheet material. The drums are heated by steam.

Salt Baths

This is a similar process to the fluidized bed process except that molten salts such as sodium and potassium nitrates are used in place of ceramic beads. A good exhaust system is needed to remove the fumes from this process. The salts are usually heated directly by electrical elements or by gas firing.

Hot Air Ovens

Products are placed and heated on a tray by natural or forced air convection. Heat is usually provided by electrical elements or gas firing.
**Induction Heating**

Electrical induction heating is sometimes used to cure the rubber on rubber coated metal rollers and larger objects with metal inserts. The metal insert is used as the conductor.

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**Figure 25 Cross section of Hot Air Oven**

**Figure 26 Induction Heating installation**
**Microwave Curing**

Costs for microwave heating is higher than other continuous cure systems but it offers rapid and evenly distributed of heat on the product and high energy efficiency. It is limited to the curing of polar compounds and those with added carbon black. After the initial heating of the product by microwave, it is normal to maintain the temperature of the product by conveying it through a tunnel of hot air.

![Microwave oven](image)

**Figure 27 Microwave oven**

Because of the large variety of products and the different types of curing processes used, it is impossible to provide a general energy consumption target that manufacturers can use to compare themselves against. As a base level from which to make comparisons, the following theoretical consumption may be useful:

- Heat rubber to cure temperature of 180 degree Celsius  \(0.085\) kWh/kg
- Force rubber into mold at 250 Bar  \(0.007\) kWh/kh
- Estimate to move press components  \(0.003\) kWh/kg
- Total energy consumption  \(0.095\) kWh/kg

A recent UK survey of rubber product manufacturers found a wide range of energy consumption for products produced from presses, ranging from a low of 0.3 kWh/kg to a high of 278 kWh/kg.

![Induction Coil](image)

**Figure 28 Induction Coil**

**Management measure**

1. In general, the actual curing time is about 25% greater than the theoretical curing time due to the variation of raw material, low curing temperature, and accuracy of timer, etc. The reduction of actual curing time as close as theoretical time can save energy.

2. Use of insulation on molds and heater plant will save energy and reduce curing time.

3. Operate the machine in such a way that the machines operate at their full capacity and avoid part load operation of machine.

**Machine/Equipment Improvement Measures**

1. Reduce curing time and energy in curing process – study the possibility to improve by considering changes of chemicals in compounds and use of new technology and machine that consumes less energy.

2. Installation of automatic controller to accurately control curing time and temperature for less energy consumption.

3. Consider the possibility to replace electric heater in mold by hot water, steam, or alternative energy sources.
4. In tire curing process of some types, it is possible to use low curing temperatures with high bladder pressures instead of high pressure, hot water. A new technique uses a mixture of steam and nitrogen which consumes less energy.

5. In general, hydraulic system in compression machine is designed to be oversized. Hydraulic pump operates all around the clock and use pressure relief value to bypass excess pressure to the storage. By this method, pump is never stopped and temperature of fluid is increased. To save energy, variable speed drive and hydraulic pump interlocks should be used to control pump.

**Machine/Equipment Replacement Measures**

Most energy in rubber production is consumed in the curing process. There are needs to research and develop new curing/vulcanizing technology such as microwave curing, induction curing, etc.

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**Advanced Technology or Measures in Rubber Industry**

- **Micro-Emulsion Technology (MEC)**

  **Possibility**
  - the readiness of the Technology: available
  - agent: available
  - confidence level: require product certificate and proof by an expert

  **Target group**
  - Production processes that require fluid fuel

  **Principle**
  - The water is injected into fuel molecule as Micro-Emulsion to increase contact surface between fuel and air. The comparison of contact surface is as follows.

  - Normal oil through burner = 13 square meters per litre
  - Oil Emulsion through burner = 130 square meters per litre
  - Micro-Emulsion = 4,300 square meters per litre

  ![Micro-Emulsion Technology Diagram]

  - Water molecules are inserted into oil droplet to increase contact surface between oil and air to get more complete combustion in an oven.
  - Water inside oil droplet will vaporize when absorb heat in the oven.
Advantages
- complete combustion to reduce energy consumption
- reduce smoke, dust and CO gas from uncompleted combustion
- replace conventional fuel with high viscosity fuel

Savings
- energy saving by 3-10 %
- additional saving if replace with high viscosity fuel

Motor Load Control with A Rubber Mill Roll

Possibility
the readiness of the Technology: available
agent: available
confidence level: require product certificate and proof by an expert

Target group
Production processes that implement a mill roller

Principle
Rollers are widely used in mixing processes of dry rubber manufacturing. Motors associated with each roller are huge and consume a great amount of energy. For a duty cycle, power required by motors are vary depend on stinginess and gradient of compound. In grinding process, rotor will continuously rotate at constant speed that is normally controlled by variable speed driver (VSD). However, energy consumed is still high because of compound variation and stinginess. Thus, there is a need for addition measures to save energy. Motor Load Control (MLC) is an option that can be implemented to control stability of supplied current and voltage based on motor load. Motor load will reduce after grinding for a while because of reduction of stinginess.

Advantages
- reduce electric energy consumption
- prolong motor life time
- soft start motor to reduce fluctuation of current

Savings
- energy saving by 5-30% based on operating conditions

Waste Heat Recovery by Heat Pipe from Exhaust Gas

Possibility
the readiness of the Technology: available
agent: available
confidence level: require product certificate and proof by an expert

Target
Production processes that require heat from boiler or hot oil boiler

Principle
Dipping products usually require heat generated by boiler or hot oil boiler to cure/vulcanize the compound. In addition, heat is used to produce hot water in leaching process. The temperature of exhaust gases from boiler is usually high and can be recovered by heat pipe. This recovered heat can be implemented in production processes to reduce consumed energy.
Advantages
- reduce fuel consumption in the hot water generator

Savings
- depend on availability and capacity of waste heat

Example
A glove rubber factory installs 450 kW heat pipe systems to recover heat from exhaust gases.
The investment is about 2.9 million baht.
The factory can save 2.2 million baht per year with payback period of 1.32 year.

Double Former for Dipping Process

Possibility
the readiness of the Technology: available
agent: available
confidence level: require product certificate and proof by an expert

Target
Products from dipping process

Principle
Malaysia is a country where dipping technology is most advanced. They use double former production line in their factories to increase productivity and reduce energy consumption.

Advantages
reduce energy consumption and increase production rate

Savings
The production rate is double and system leakage is also reduced. Energy consumption per unit reduces by 30%.

Waste Water Treatment by Membrane Technology

Possibility
the readiness of the Technology: under research and development
agent: -
confidence level: -

Target
Products from dipping process

Principle
- A type of membrane can be used at different temperature, such as organic membranes are good below 150 degree Celsius. Inorganic membranes can be used above that depending on materials, for example, metal is good between 500-800 degree Celsius, ceramic is for application greater than 1000 degree Celsius. In case of dipping process, organic membrane is suitable.
- For membrane separation process, there are various types and costs such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), osmosis (RO), electrodialysis (ED), gas separation and pervaporation. Implementation of membranes must be carefully considered.
- Use of chemical-treated waste water may not be suitable of dipping products because of chemical solution in the water that affects quality of the products. The implementation of membrane treatment is another treatment possibility.
Advantages/Disadvantages

- reduce water usage in the production process by waste-treated water
- additional cost on membranes and water circulation systems

Figure 30 Principle Water Treatment of Membrane

Figure 31 The FILMTEC membrane

Figure 32 Cross section enlarge 100 time of membrane fiber
Conclusion

Rubber industry and rubber products sector is one of the industries that is significant to the economy of the country because of its position as an industry sector that Thailand clearly has an advantage in terms of raw materials, which is the first latex rubber producer and exporter in the world, and the growth of the industrial sector tends to expand continuously. Although many competitors exist in the world market, the result of this project found that the average specific energy consumption index (Average SEC) of the rubber industry and rubber products sector is 21.78 MJ per kilogram of production. The average standard energy consumption (Average Benchmark) of the rubber industry and rubber products sector is 16.07 MJ per kilogram of production, but the specific energy consumption and benchmark value differ in each sub-sector by energy. Entrepreneurs in the rubber industry can divide into 9 sub-sectors to enable specific energy consumption to be comparable with benchmark value in each group. An overview found that the rubber industry and rubber products sector have a few significant potential for energy consumption compared to other industrial sectors, with Energy Intensity of 0.412 MJ per unit of value added, which is lower than the average of the total industrial sector, and Energy Elasticity of 0.463, lower than 1. The part in terms of conservation energy development of the industrial sector is in the case of an average different value of specific energy consumption and benchmark based on the load of production quantity, found that there is conservation energy potential in the overall of the industry sector of 32.43, which is the result of analysis both by entrepreneurs, experts, and professional personnel summarized the confusion issue in 4 points and set tactics in order to solve the aforementioned results in 8 energy conservation plans that consist of short-term, medium-term, and long-term as shown in Unit 4 of this document including the verification of the results that indicate that the reduction of specific energy consumption must be more than 10% per year, coupled with the supply of Technology and energy conservation measures that consist of general measures and appropriate technology that can be researched and applied in rubber factories, as detailed in Chapter 5 of this document.

The result of this project is the driving force for promoting energy conservation in the rubber industry and rubber products sector in a more sustainable manner in order to improve the efficiency of energy consumption of the industrial sector that is a significant production sector of the country and enhance the potential in the competition of Thai industry sector in the world market, including entrepreneurs in the industry sector can solve problems from energy critical in the present and the future together.