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Final Report

Widening the coverage of PAT Scheme

Sectoral Manual - Vegetable oil industry

Prepared for

Shakti Sustainable Energy Foundation

The Energy and Resources Institute

...towards global sustainable development

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Disclaimer

This report is part of Shakti Sustainable Energy Foundation (SSEF) and The Energy and Resources Institute's (TERI) attempt to study the Vegetable Oil Refinery energy consumption trends and energy efficiency improvement opportunities in the Vegetable Oil Refinery in India. The views expressed in this document do not necessarily reflect the view of Shakti Sustainable Energy Foundation. The organisation accepts no liability for the content of this document, or for the consequences of any actions taken on the basis of the information provided. While every care has been taken in compiling this report, TERI and Shakti Sustainable Energy Foundation accepts no claim for any kind of compensation, if any entry is wrong, abbreviated, omitted or inserted incorrectly either as to the wording space or position in the report.

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The Energy and Resources Institute (TERI)

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List of abbreviation

BEE	-	Bureau of Energy Efficiency
BIS	-	Bureau of Indian Standards
BOT	-	Bleached Oil Tank
CIS	-	Commonwealth of Independent states
CPO	-	Crude Palm Oil
DCs	-	Designated Consumers
ESCerts	-	Energy Saving Certificates
ETPI	-	Environment Technology Program for Industry
EU-27	-	European country
FFA	-	Free Fatty Acid
FSU	-	Former Soviet Union
GHG	-	Green House Gas
GoI	-	Government of India
Mha	-	Million hectares
MSP	-	Minimum Support Price
Mtoe	-	Metric Tonne of Oil Equivalent
mMt	-	Million Metric tonne
NAPCC	-	National Action Plan on Climate Change
NMEEE	-	National Mission on Enhanced Energy Efficiency
NOT	-	Neutralized Oil Tank
NPC	-	National productive Council
OGL	-	Open General License
OTA	-	Oil Technologists' Association of India
PAT	-	Perform Achieve and Trade
PDS	-	Public Distribution System
SEA	-	Solvent Extractors' Association of India
SEC	-	Specific Energy Consumption
SSEF	-	Shakti Sustainable Energy Foundation
TERI	-	The Energy and Resources Institute
TPD	-	Tonne per Day
USDA	-	U. S. Department of Agriculture
VOC	-	Volatile Organic Compound
VSD	-	Variable Speed Drive
List of measuring units		
kCal	-	Kilo Calorie
kg	-	Kilogram
kWh	-	Kilo Watt Hour
MT	-	Metric Ton
Mha	-	Million hectares
MTOE	-	Metric Ton of Oil Equivalent
List of conversion factors		
1 MCal	-	10^3 kCal
1 kJ	-	4.18 kCal
1 kCal	-	860 kCal
1 MTOE	-	10^7 kCal

1.0 Executive summary

The Bureau of Energy Efficiency (BEE) is entrusted with the implementation of the National Mission on Enhanced Energy Efficiency (NMEEE) using the Perform, Achieve and Trade (PAT) scheme and the expected energy savings from this is about 6-8 million tonnes of oil equivalent (mMtoe). The BEE plans to widen the coverage of the PAT scheme, in subsequent phases, by adding new industrial subsectors based on the energy consumption. This subsector overview report on the vegetable oil industry provides information on large and medium manufacturers in this sector in terms of number of existing plants, production capacity, capacity utilization, energy efficiency levels and estimated energy saving potential.

The Indian vegetable oil industry accounts for about 5% of the world's vegetable oil production. The estimated demand for vegetable oil is over 18mt (million tonnes) which is predominantly met by imports. India's share in the world's vegetable oil imports is about 14 per cent.

The vegetable oil industry is classified into four categories - small scale expellers / Ghanis, solvent extractors, oil refiners and vanaspati manufacturers. The vegetable oil refinery industry is the largest energy user in the vegetable oil processing sector as compared to crushing and solvent extraction industries. There are about 1060 vegetable oil refineries operating in India, most of which are of small scale type with capacities ranging from 5 tpd to 100 tpd. There are 13 major vegetable oil refineries with capacities varying from 300 tpd to 1000 tpd. The capacity utilisation of major vegetable oil refineries is about 35 to 40% which is low. There are significant opportunities available to these refineries for utilizing effectively the existing capacities either through enhancing the availability of oil seeds at domestic level or through crude oil imports for further processing.

The higher energy consumption of refineries depends on various factors such as (1) type of oilseed being processed (palm oil and sunflower oil require winterisation for separation of wax), (2) capacity utilization and (3) types of fuels used. The 13 major refineries account for about 70-75% of vegetable oil processing in India. The total energy consumption of these major oil refineries is estimated to be in the range of 80,000 to 90,000 Mtoe per year, which is quite significant. Various studies in India as well as other countries show that there is significant potential for energy efficiency improvements. There exists an energy saving potential of 5% to 8% in major oil refineries operating in India. It may be concluded that future interventions in vegetable oil sector must focus on major oil refineries to achieve higher energy savings in the sector.

It is recommended that the vegetable oil refinery industry may be considered to be included as 'Designated Consumers' (DCs). A threshold limit of 3000 Mtoe may be considered for vegetable refinery industries for including them as DCs. This is equal to the threshold limit for textile industries. By considering a threshold limit of 3000 Mtoe, about eight numbers of major refineries could get included as DCs and become part of the second phase of PAT.

2.1 Introduction

The Bureau of Energy Efficiency (BEE) has been entrusted with the implementation of the National Mission on Enhanced Energy Efficiency (NMEEE) under the National Action Plan on Climate Change (NAPCC). One of the key components of the mission is the Perform, Achieve and Trade (PAT) mechanism. PAT is a market based mechanism to improve the energy efficiency in large energy intensive industries and facilities cost-effectiveness by certifying energy savings that could be traded. The PAT mechanism is designed to facilitate the Designated Consumers (DCs), who are the large energy consumer to achieve their legal obligations under the Energy Conservation Act (EC Act) 2001, which was amended in 2010.

The ensuing PAT scheme applies to 8 industrial sub-sectors, namely aluminium, pulp & paper, chlor- alkali, cement, iron & steel, textile and fertilizers and power plants. As per the recent notification, during the first phase of the PAT cycle (3 years starting from 1st April 2012), about 478 DCs have been identified, which are obliged to reduce their energy consumption by a specific target given by the BEE. The expected energy savings under PAT scheme is about 6.6 million tonnes of oil equivalent (mMtoe) during this period. DCs which achieve higher energy savings than set targets will earn tradable Energy Saving Certificates (ESCerts); and the 'under achievers' need to comply targets through purchase of ESCerts or by paying penalty.

The BEE has planned to widen the existing coverage of the PAT scheme, in subsequent phases, by including new industrial subsectors based on their energy consumption levels. There is a need to study the energy consumption in detail for the new industrial segments to establish the threshold limit for the eligibility for DCs. Shakti Sustainable Energy Foundation (Shakti or SSEF), which functions as a partner institution of the Climate Works Foundation, is assisting BEE in consultation with TERI for widening the range of the PAT scheme by including new subsectors in subsequent phases of the PAT scheme. The focus of SSEF is to strengthen the energy security of India by aiding design and implementation of policies that support energy efficiency and renewable energy. Shakti has identified four industry sub-sectors to study the energy consumption details and explore threshold limits for further nomination as DCs. The industrial subsectors identified by SSEF include the following:

- Copper and zinc
- Glass and ceramics
- Sugar industry
- Vegetable oil refineries

The initial task is to map the identified four sub sectors in the Indian context and prepare broad sectoral reports. This subsector overview report provides information on large and medium manufacturers, number of plants in different categories, production capacities, technologies used and technological development in last decade, capacity utilization, energy efficiency levels, energy saving potential and barriers for implementation of energy efficient technologies & measures, and regulatory & policy issues that have bearing on improving energy efficiency in the sub-sectors.

The purpose of the sectorial report is mainly to understand the energy intensity of the subsector, technology adopted and its energy efficiency levels. It also assesses the potential for reduction in energy consumption across the subsector and identifies technological gaps. The report also provides an overall energy scenario of the subsector.

This overview report has been prepared based on secondary information available in public domain. Further data and information were collected through interactions with the industrial associations of the subsector. The report comprise of the following sections:

- Overview of vegetable oil sector
- Analysis of energy consumption data
- Energy performance
- Conclusions and recommendation

This overview sectoral report is an integral part of the research study on "Widen the coverage of PAT scheme".

2.1 Sector Importance

India is one of the largest producers of oilseeds in the world and has a wide range of oilseeds crops grown in different agro climatic zones. India's share in the world oilseed production is about 8%. The estimated demand for vegetable oil is over 18mt (million metric tonne) which is predominantly met by imports. Vegetable oils can be edible or non-edible. The vegetable oils are mostly derived from the particular plants or may be a blend of two or more oils. In India, different varieties of edible oils are consumed, depending mostly on regional preferences and their availability.

The per capita consumption / demand of vegetable oils in India have increased rapidly over past decade. The increase in demand may be attributed, to a combination of factors such as population growth, improved living standards, changing diets, etc. The price of vegetable oil is on an upward trend due to low stock, droughts, changing weather patterns and processing cost.

Vegetable oil processing will remain as one of the largest industrial segments in India as vegetable oil consumption is set to increase exponentially. The overall economics of the vegetable oil production industry is significantly influenced by effective by-product utilization to produce value added products. This sector occupies a distinct position in Indian economy as it provides job opportunities to millions of people, achieves on an average a domestic turnover of US $ 10 billion per annum and earns foreign exchange of US $ 90 million per annum.

It is extremely important to use latest technologies for processing vegetable oils so that it retains valuable nutrients in the processed oil, reduces specific energy consumption to thereby keeping the processing cost low and also meets the stringent environment emission norms.

2.2 National / International scenario

India is the fifth largest oilseed producing country in the world, producing around 35 million tonnes of oil seeds in 2011-12 and having around 41.11 million hectares under oil seed cultivation. India's share in the world oilseed production is around 8 percent. The break-up of the worldwide oilseed production is given in Figure 2.2. The details of oilseed production and area under cultivation are given in **Appendix 2/1.**

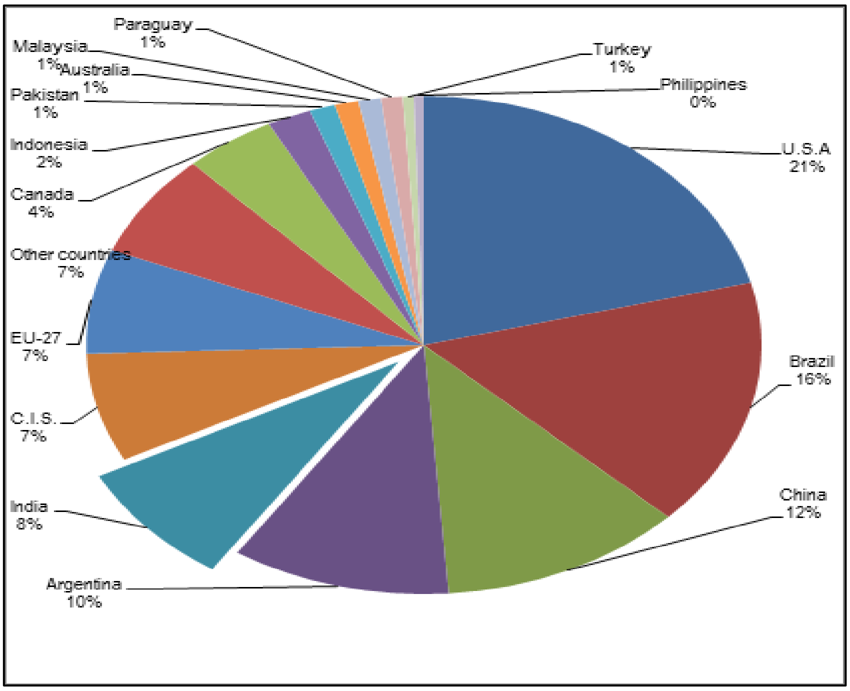

Figure 2.2: World oilseed production (2011-12)

(Source: Oil World, Hamburg, Germany)

EU-27: European country; CIS: Commonwealth of Independent states

2.3 International standing of subsector

About 80% of the world's total edible oil is of vegetable origin, obtained from oilseeds, nuts, fruits and grains. The global production and consumption of major oilseeds and vegetable oils have been increasing continuously since 1978-79. The total harvesting area for major oilseeds increased (by 54%) from 120.4 million hectares (USDA, 2003) to 257 million hectares (Oil World, Hamburg, Germany) and production (by 200%) from 142.15 million tonnes to 435 million tonnes from 1978/ 79 to 2011/ 12. On the other hand, trade (import and export) of vegetable oil has increased tremendously (by about 300%) from about 18.6 million tons (sum of import and export) in 1997/ 98 to 75 million tons in 2001/ 02 (USDA, 2003). The global market for oilseeds and oils is expected to grow, roughly in line with the world's population.

Most of the oilseeds and vegetable oil are produced in North and Latin America and in Asia. Comparatively, cultivation in Europe, Africa and Australia is significantly less. In 2011-12, United States accounted for about 21% of the total global oilseed production followed by Brazil (16%), China (12%), Argentina (10%) and India (8%). USA and Latin America produces most of world's soybean, while Asia produces most of the cottonseed, peanut and rapeseed. Argentina and the former Soviet Union (FSU) are the highest producers of sunflower seed. Malaysia and Indonesia accounts for most of the palm oil, palm kernel and copra oil produced in the world. Almost all the major producers of oilseeds show higher yield of crop compared to the world's average except India, which shows a very low yield. The yields for different types of oilseeds is very high in USA, China and Brazil due to better cultivation techniques, machineries and application of genetically engineered crops.

2.4 Market scenario

India accounts for about 5% of world vegetable oil production and 14% of the world's vegetable oil sources (oilseeds, nuts, fruits & grains). India also imports 10.2% of the world's edible consumption (as of March 2013). As against the demand of edible oils, oilseed production in India has remained largely stagnant due to low productivity in under-irrigated areas and shifting of acreage from oilseeds to other crops. Imports have been further incentivised by a sharp cut in duties. This had resulted in a surge in volumes of imported oils and currently meets almost 45-50% of the domestic consumption requirements. Refined and Crude Palm Oil (CPO) accounted for the major portion of edible oil imports in India (75% during November-2011 to October-2012) mainly due to their relatively low prices and availability in high quantity. The dependence on the imported edible oils is expected to increase in future due to anticipated domestic supply constraints and the high cost competitiveness of imported oils. Import of the edible crude and refined oil from 1996-97 to 2011-12 is given in **Appendix 2/2** and the total import oil is given in Figure 2.4.

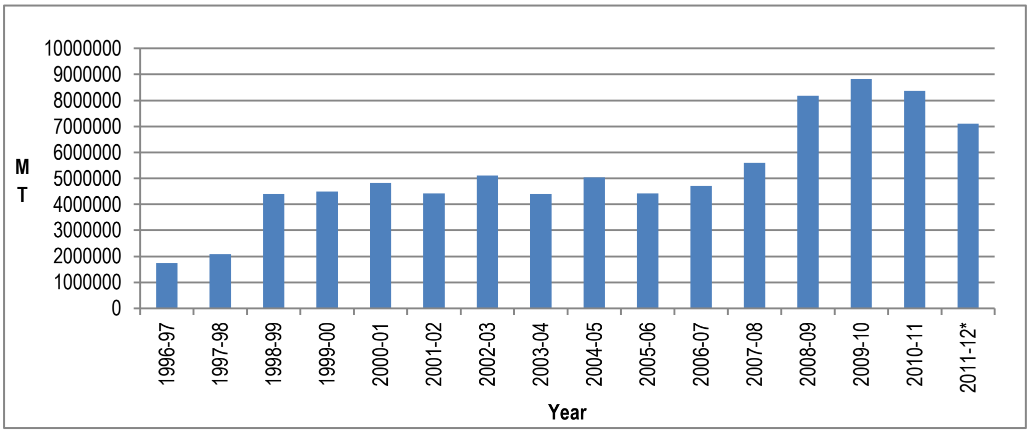

Figure 2.4: Import of refined oil and crude oil

Source: SEA Annual Report
2011-12- up to July*

The export of edible oils was initially prohibited but exemption have been grated for few vegetable oils through various notifications issued namely (i) export of castor oil (ii) export of coconut oil through Cochin Port (iii) Deemed export of edible oils (as input raw material). In addition, export of edible oils in branded consumer packs of up to 5 kg with ceiling of 20,000 tonnes is permitted. Due to these notifications export of edible oil reduced from 2008 to 2010 but increased in 2011-12. The details of export of vegetable oil are given in Table 2.4.

Table 2.4: Export of edible oils (Metric tonne)

Type	2007-08	2008-09	2009-10	2010-11	2011-12
Groundnut	28,810	14.51	4.80	1,683.9	1,931.89
Soyabean	16,623.86	467.91	214.18	478.32	10,210.16
Sunflower	7,740.18	289.39	857.54	1,190.32	1,072.75
Mustard	1,656.36	1,022.8	1,514.62	1,212.51	1,018.31
Sesame	3,801.45	1,040.62	1,966.14	2,861.56	3,756.14
Coconut	84.61	53.11	14.13	69.33	292.55
Maize	68.16	3.07	2.01	35.47	5.00
Cottonseed	573.9	0.86	0.44	44.21	151.25
Rice bran	140.16	233.75	925.93	254.67	130.6
Total	59,499	3126	5,500	7830	18,569

Source: SEA Annual Report

2.5 Growth in past and future prospective

The world vegetable oil production has increased continuously in the past decades. The main growth has been in palm oil (representing more than 30% of vegetable oil production in2007), soyabean oil (28%), rapeseed oil (15%) and sunflower oil (9%). Based on the data from Oil World (2012), the world oil production of soybean oil, groundnut oil, rapeseed/ mustard oil, cottonseed oil, sunflower/ sesame/ safflower oil, palm oil and other oils (rice bran/ copra etc.) is 43.54 mMt, 4.21 mMt, 23.69 mMt, 4.89 mMt, 14.7 mMt, 54.9 mMt and 42.79 mMt respectively. The remaining share accounts for less than 20% of the market. The details of the world vegetable oil production are given in Figure 2.5.

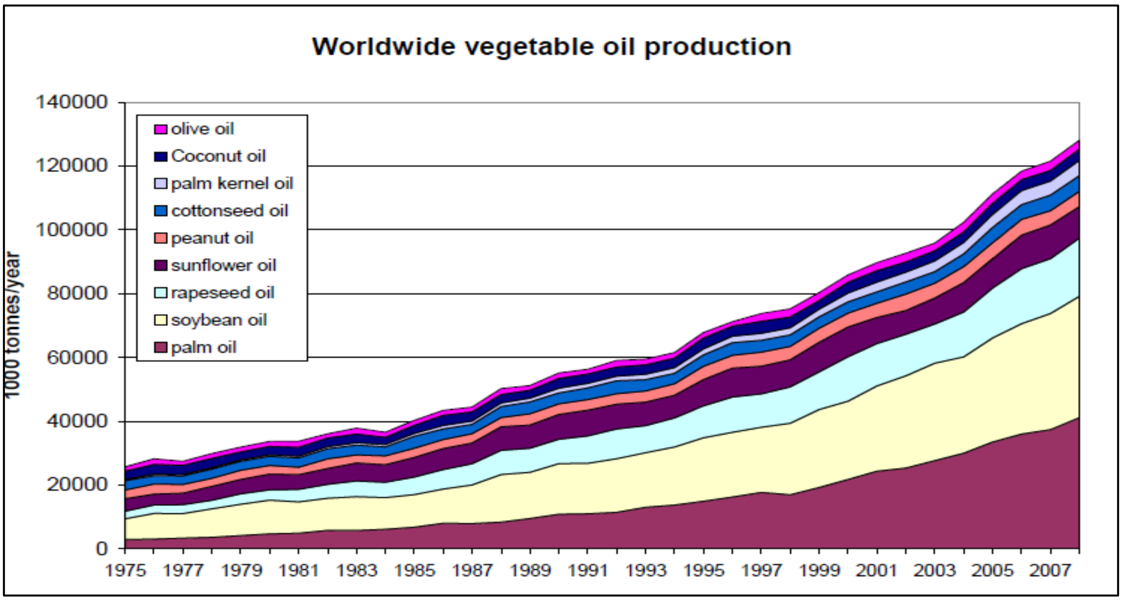

Figure 2.5: World vegetable oil production

Source: www.fas.usda.gov/psdonline

From figure 2.5 it can be seen that there is continuous global annual growth of vegetable oils production during the period 1987 to 2007. Palm tops the increase with over 8.1% annually, followed by palm kernel with 7.6%, and soybean oil with 5.7%. The average growth of vegetable oils from 1987 to 2007 is given in Table 2.5.

Table 2.5: Growth of vegetable oil sector (1987 to 2007)

Description	Growth per year (%)
All vegetable oils	5.2
Palm oil	8.1
Soyabean oil	5.7
Rapeseed oil	4.8
Sunflower oil	2.5
Palm kernel oil	7.6
Cottonseed oil	2.5
Olive oil	3.2
Peanut oil	2.1
Coconut oil	0.8

Source: www.fas.usda.gov/ psdonline

The demand for edible oil is expected to increase to 21.3 mMt by 2015. This assumes a per capita consumption increase of 4% and a population growth of 1.7% which translates to an overall growth in demand at 6% per annum.

2.6 Production data

The total requirement of edible oil in India was 18.15 million metric tonne (mMt) in 2010-11 of which 8.37 mMt were imported and the balance 9.6 mMt was met with domestic production. In terms of volumes, palm oil, soyabean oil and mustard oil were the three largest edible oils consumed in India, sharing 46%, 16% and 14% respectively in total oil consumption in 2010.The estimated availability of various edible oils in India for 2011-12 is given in Table 2.6.

Table 2.6: Availability of edible oil in India (2011-12) (In million Metric tonne)

Oil	Domestic production	Import of edible oils	Total
Soybean	1.76	1.10	2.86
Groundnut	0.12	-	0.12
Rapeseed / Mustard	2.01	-	2.01
Cottonseed	1.13	-	1.13
Sunflower/ Sesame/ Safflower	0.21	1.00	1.21
Palm	0.08	7.90	7.98
Other Oils (Rice Bran/ Copra etc.)	2.14	-	2.14
Total	7.45	10.0	17.45

Source: 1. Oil World, 2012 and SEA (Solvent Extractors' Association) data bank for India
2. The Soybean Processors Association of India, Indore, March 2013

2.7 Important stakeholders

The edible oil and oilseeds sector in India faces many challenges in the new environment of liberalized trade. Government intervention is faced with the task of balancing the interests of different stakeholders in the oilseed complex. There are also few academic institutes/ research organisations in India that are undertaking various research activities related to vegetable oil sector in the country. Major stakeholders of the vegetable oil industry in the country are:

2.7.1 The National Oilseeds and Vegetable Oils Development (NOVOD) Board

The National Oilseeds and Vegetable Oils Development (NOVOD) Board, a statutory body under the National Oilseeds and Vegetable Oils Development Board Act, 1983 for the integrated development of oilseeds and vegetable oils industry in the country. The Board is under the administrative control of Department of Agriculture and Cooperation of Ministry of Agriculture, Government of India. The objectives of the board include develop and refine the technologies for improved productivity & quality and create awareness through training, publication and publicity.

2.7.2 The solvent extraction association of India (SEA)

The Solvent Extractors' Association of India was formed to help and foster the development and growth of solvent extraction industry in India. Associate membership of the association includes processors, merchant exporters, oil millers, refiners, vanaspati manufacturers, importers of edible oils, brokers, traders, plant & machinery manufacturers, clearing & forwarding agents, surveyors, regional associations etc.

2.7.3 Oil technologists' association of India (OTAI)

The Oil Technologists' Association of India (OTAI) is engaged in disseminating the latest information with regard to scientific and technical developments through workshops, refresher courses and lectures.

Apart from these institutes/ organisations, food & beverage sector, pharmaceutical etc. are also important stakeholder in this sector.

2.8 Product categorisation

In India, groundnut, rapeseed / mustard, sesame, soybean, sunflower, safflower, niger, linseed and castor are major cultivated oilseeds crops. Of these, groundnut, soybean and mustard together contribute to about 86 percent of the country's oilseed production. The production details of oilseeds from 2001 to 2012 are given in **Appendix 2/3** and the details for 2010-11 are given in Figure 2.8.

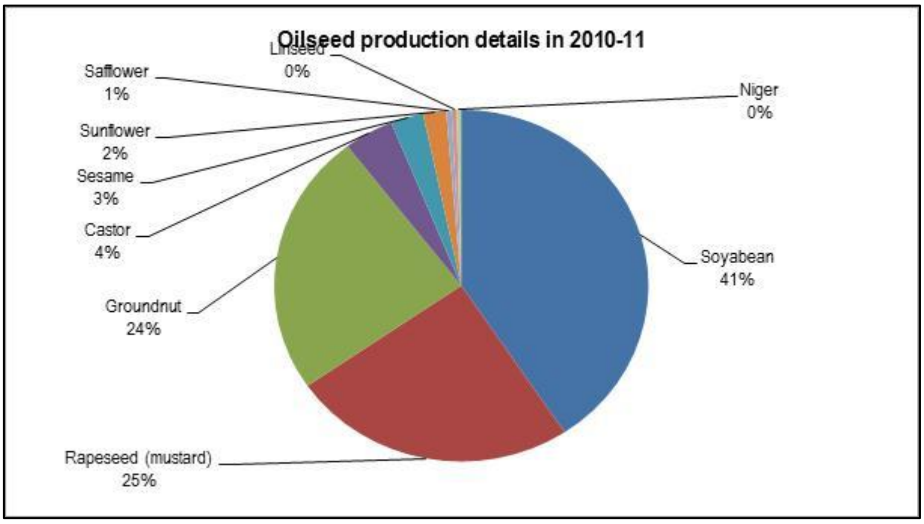

Figure 2.8: Oilseed production details in 2010-11

Source: SEA Annual Report

The production details of oilseeds and vegetable oil in India are given in Table 2.8.

Table 2.8: Production of oilseeds and vegetable oil in India (million Metric tonne)

Year (Nov-Oct)	Oilseed production	Availability of vegetable oil		
		Edible	Non-edible	Total
2012-13 (E)	29.46	6.8	0.65	7.45
2011-12	29.80	7.34	0.78	8.12
2010-11	32.48	7.92	0.60	8.52
2009-10	24.88	7.26	0.51	7.77
2008-09	27.72	7.71	0.50	8.21
2007-08	29.76	7.75	0.49	8.24
2006-07	24.29	7.33	0.43	7.76
2005-06	27.98	7.56	0.47	8.03
2004-05	24.35	7.16	0.43	7.59
2003-04	25.18	7.21	0.38	7.59

2.9 Major players

In the vegetable oil industry, the solvent extraction and refining units are undergoing a phase of consolidation and becoming more concentrated. The edible oil industry is highly fragmented with over 600 oil extraction units and 166 vanaspati manufacturing unit. Currently, around 25% of the turnover is accounted by 12 to 15 players out of a total of 600 players. A list of the major players in the vegetable oil industries is given in Table 2.9.

Table 2.9: List of major players in vegetable oil production

Sr No	Industry Name	Capacity (tonne/day)	Brand Name
1	Adani Wilmar	9,000 (9 plants)	Fortune
2	Ruchi	6,000	Nutrela, Ruchi
3	Marico	570	Saffola
4	Cargill	4,851	Gemini
5	National Development Board	-	Dhara
6	K S Oil	1,644	Kakash
7	Sanwaria	850 (3 plants)	Narmada, Sulabh, Sanwaria
8	Anil Industries	700 (2 plants)	Nutrela (part of Ruchi group)
9	Vimal oil	300	Kriti
10	Ashiana	-	Ashiana
11	GokulRefoils	1,000	Gokul
12	Emami	3,300	Emami
13	Amrit	330	Amrit

2.10 Current regulatory/ policy scenario

In pursuance of the Government policy of liberalization, there have been progressive changes in the import policy with respect to edible oils during last few years. In order to collectively address the interests of farmers, processors and consumers, the import duty structure on edible oils is reviewed on a regular basis. The existing regulatory Acts applicable for edible oil segment are given below.

- The Vegetable Oil Products (Control) Order, 1947.
- The Edible Oils Packaging (Regulation) Order, 1998.
- The Solvent Extracted Oil, De-oiled Meal, and Edible Flour (Control) Order, 1967.
- Bureau of Indian Standard (BIS) requirements for mandatory Food products.
- The Prevention of Food Adulteration Act, 1954 (37 of 1954) and Rules 1955.

3.0 Energy performance

3.1 Sectoral level energy performance in recent years

Vegetable oil production is typically a two-stage process namely extraction of oil from seeds or fruits and refinement of the crude oil. The current practice is expelling followed by solvent extraction. Vegetable oil is extracted from the oilseeds using a solvent, such as hexane. Extraction and refining of vegetable oil is energy intensive process due to the requirement of heating and cooling at various steps of processing.

The crude oil is refined to remove undesired impurities such as gums, free fatty acids (FFA), traces of metals, colouring components, and volatile components. Degumming is an essential step of the physical refining process because the oil entering the final deodorization has to have a low content of phosphatide. Degumming methods can either be acidic or enzymatic. Degummed oil has a phosphorus content of less than 30 parts per million (ppm). Citric acid may be used instead of phosphoric acid, which brings a range of advantages, including reduced phosphorus load in the wastewater and a slight reduction in the amount of sludge. Enzymatic degumming uses enzymatic hydrolysis of the phosphatides.

3.1.1 Chemical refining

Conventional chemical refining involves degumming for the removal of phospholipids, neutralization for the removal of FFA, and bleaching for decolourization and deodorization. Water is added during degumming to hydrate any gums present and the mixture is then centrifuged for separation. Non-hydratable gums are removed using phosphoric or citric acid before water is added and separation takes place in a centrifuge. During degumming, caustic soda is added to the oil, which has been preheated to between 75oC and 110oC to saponify the FFA. The soap stock formed is heated to between 70oC and 100oC and reacts with sulphuric acid to reform the fatty acids.

3.1.2 Physical refining

Physical refining is a more simple process in which the crude oil is degummed and bleached, and then steam stripped to remove FFA, odour, and VOCs all in one step. Following this, FFA is stripped from the pre-treated oil using steam in a vacuum at temperatures of around 250oC and refined by the oil flowing over a series of trays. A scrubber is used to condense the greater part of the fat from the vapours as a water-free product.

Fossil fuels are used in boilers for steam generation and electricity to run machineries in different process sections. The energy requirement varies widely from mill to mill About 30 tonnes of high grade coal and 20,200 kWh of electricity are required in Indian oil mills for extraction of 500 tonnes of soybean seed and refining 100 tonnes of oil (NPC, 2002).

Detail process description of vegetable oil sector is given in **Appendix 3.1** and the basic unit operations in vegetable oil processing are shown in Figure 3.1.2.

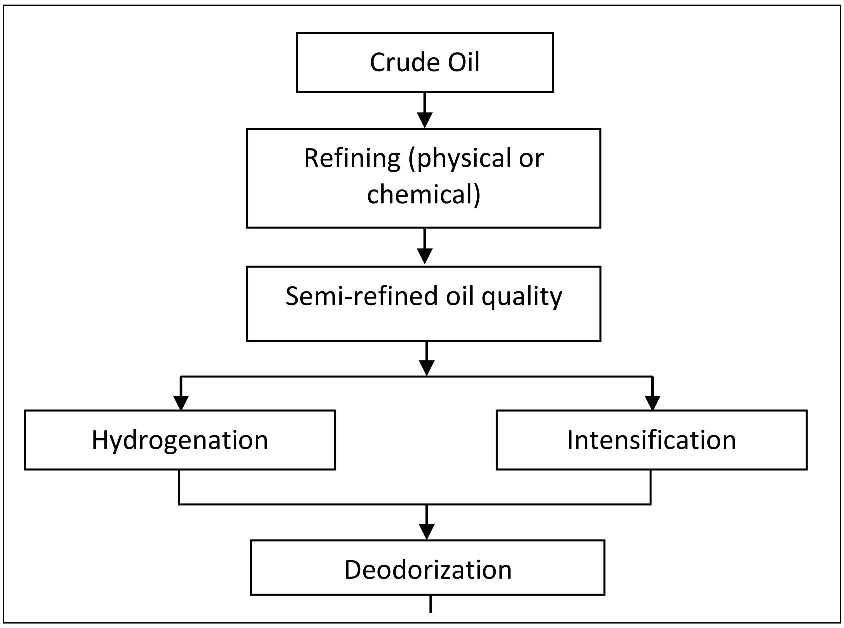

Figure 3.1.2: Vegetable Oil production process

The energy performance i.e. specific energy consumption (SEC) of the vegetable oil refinery (except Palm and Sunflower) of different capacities is given in Table 3.1.2a to Table 3.1.2c.

Table 3.1.2a: SEC of a 100 TPD crude oil refinery (except Palm & Sunflower)

Particulars	Unit	Value
Electricity consumption	kWh/ tonne of oil	40
Coal for steam generation	kg/ tonne of oil	70
Coal for high temp deodorisation by using Thermic fluid	kg/ tonne of oil	10
(or)		
Coal for high temp deodorisation by using Thermosiphon	kg/ tonne of oil	8

Source: SEA Technical Committee (2013)
(Thermic fluid or Thermosiphon is used for heating the oil at high temperature in deodorisation process)

Table 3.1.2b: SEC of a 500 TPD crude oil refinery (except Palm & Sunflower)

Particulars	Unit	Value
Electricity consumption	kWh/ tonne of oil	36
Coal for steam generation	kg/ tonne of oil	63
Coal for high temp deodorisation (thermic fluid)	kg/ tonne of oil	9

Source: SEA Technical Committee (2013)

Table 3.1.2c: SEC of a 1000 TPD crude oil refinery (except Palm & Sunflower)

Particulars	Unit	Value
Electricity consumption	kWh/ tonne of oil	34
Coal for steam generation	kg/ tonne of oil	60
Coal for high temp deodorisation (Thermic fluid)	kg/ tonne of oil	8.5

Source: SEA Technical Committee (2013)

The SECs of the fractionation (extra process to remove triglyceride) in vegetable oil refinery (for Palm and Sunflower) of different capacities (100 TPD, 500 TPD & 1000 TPD) and 500 TPD solvent extraction plant are given in Table 3.1.2d to Table 3.1.2g respectively.

Table 3.1.2d: SEC of 100 TPD refinery (for Palm oil &Sunflower oil)

Particulars	Unit	Value
Fractionation		
Steam for vapour absorption chiller	kg/ tonne of oil	150
Electricity consumption	kWh/ tonne of oil	10 to 15

Source: SEA Technical Committee (2013)

Table 3.1.2e: SEC of a 500 TPD refinery (for Palm oil &Sunflower oil)

Particulars	Unit	Value
Fractionation		
Steam for chilled water generation	kg/ tonne of oil	135
Electricity consumption	kWh/ tonne of oil	9 to 13

Source: SEA Technical Committee (2013)

Table 3.1.2f: SEC of a 1000 TPD refinery (for Palm oil & Sunflower oil)

Particulars	Unit	Value
Fractionation (extra process to remove triglyceride)		
Steam for chilled water generation	kg/ tonne of oil	132
Electricity consumption	kWh/ tonne of oil	8.5 to 13

Source: SEA Technical Committee (2013)

Table 3.1.2g: SEC of a 500 TPD solvent extraction plant

Particulars	Unit	Value
Electricity consumption	kWh/ tonne of oil	30
Steam	kg/ tonne of oil	300
Solvent loss	lit/ tonne of oil	3

Source: SEA Technical Committee (2013)

The SEC of a 500TPD solvent extraction and 200TPD crushing unit is given in Table 3.1.2h.

Table 3.1.2h: SEC of a typical 500TPD solvent extraction plant & 200TPD crushing unit

Particulars	Unit	Solvent extraction plant (500TPD)	Crushing Units (200TPD)
Electricity consumption	kWh/ tonne of oil	30	100
	MCal/ tonne of oil	25.8	86
Steam	kg/ tonne of oil	300	50
Thermal energy equivalent to steam	Mcal/ tonne of oil	150	27
Specific energy consumption	MCal/ tonne of oil	175.8	113
	Mtoe/ tonne of oil	0.018	0.011
Solvent loss	lit/ tonne of oil	3	

Source: SEA Technical Committee (2013)

In most oil mills, the boilers consume a significant share of the total energy. Several factors determine the energy consumption in boilers such type of boiler, boiler efficiency, age of boiler, operating conditions etc. Boiler efficiency is found to be typically low (60-70%) in a number of oil mills. Energy efficiency of the mill in general is found to be lower in small and medium units due to use of old equipment, line losses (leakage, absence of proper insulation), steam losses, condensate losses, losses in cooling towers, poor maintenance and sub optimal operational procedures.

The energy performance of one of the leading vegetable oil refineries is given in this section as a case study. The plant has a 1000 TPD Refinery and a 200 TPD vanaspati plant. The annual production of the plant was 0.19 mMT in 2007-08 with a capacity utilization of about 55%. The electricity and coal consumption were around 95.55 MWh and 9000 MT respectively. The total energy cost was estimated to be Rs 69.5million. Electricity was mostly used for the pumping system and chilled water generation. Coal was used in the boiler to generate steam and thermic fluid heater/ Thermo siphon for heating oil/ water. The power consumption was 17% and the thermal energy consumption was 83% of the total energy (4867 Mtoe).The details of the energy consumption of the plant are given in **Appendix 3/2** and the specific energy consumption details are given in Table 3.1.2i.

Table 3.1.2i: Energy consumption of the refinery

Particulars	Unit	2005-06	2006-07	2007-08
Capacity of the plant	TPD	1,000	1,000	1,000
Total production	MT	1,12,295	1,27,399	1,89,910
Capacity utilization	%	31	35	52
Electrical consumption	Million kWh	6.278	8.857	9.555
	Mtoe	539	761	821
Thermal energy	M kCal	31,779	34,016	40,451
	Mtoe	3,178	3,402	4,045
Total energy consumption	Mtoe	3,718	4,163	4,867
Share of electricity consumption	%	15	18	17
Share of thermal energy consumption	%	85	82	83
Total energy cost	Rs in million	40.65	55.91	69.47
Manufacturing cost	Rs in million	4620	5205	8,034
% of energy cost	%	0.88%	1.07%	0.86%

Source: Vegetable oil industry/ plant annual report (from 2005 to 2010)

3.2 International comparison

Discussions were held with the members of the Solvent Extraction Association (SEA) on the international and Indian scenario for comparing between the Indian and International refineries. The discussions revealed that the processes used by both were the same, but the SEC level of international refineries in the vegetable oil sector was lower as compared to India. This was mainly attributed to larger capacity of processing and better capacity utilisation of the international plants.

3.3 Technological movement

The manufacturing process of the vegetable oil sector in India has not changed significantly over time. Various types of technologies used at different stages of the manufacturing process to improve production yield and quality are briefly described as follows:

3.3.1 Nano neutralization

Nano neutralization process offers enhanced performance by improving oil yield, low operating cost, reduce environmental impact and yields better oil quality. The neutralization of free fatty acids transforms them into soaps followed by the separation step. The procedure also removes non-hydratable phosphatides and decreases the level of impurities.

3.3.2 Improvement in filtration

Replacing filter presses with pressure leaf filters which give benefits in terms of expanded capacity, utility savings and ease of operation. By using leaf filter presses, olein yields in palm oil fractionation could be raised close to 80%

3.3.3 Continuous bleaching and deodorizer

Continuous bleaching systems as an upgrade to batch system, so that achieve still higher production capacities, consistent quality, ease of operation and an automated dosing of chemicals. Due to that achieve quality in comparison to that offered by the multinationals.

Other energy conservation options include recovery of condensate, installation of regeneration system for effective waste heat recovery and auto temperature controls system in distillation and de-solventised systems.

3.4 Capacity utilisation

The vegetable oil refineries are classified as refinery with vanaspati unit, refinery with solvent unit and independent refinery. Details on the number of refinery and the estimated installed capacity and utilization are given in Table 3.4.

Table 3.4: Status of vegetable oil industry in India (as on January 2010)

Type	Numbers of units	Annual installed Capacity* (million MT)	Capacity utilisation (%)
Refineries attached with vanaspati units	135	5	45
Refineries attached with solvent units	310	3.8	25
Independent refineries	615	4.5	32
Average of all refineries	1,060	13.8	35

*in terms of oil

Source: LokSabha Unstarred Question No. 1861, dated on 09.03.2010.

The vegetable oil refinery in India is characterized by under-utilized capacities. The underutilization of capacities is attributed to lack of raw materials and difficulties faced for import of oilseeds (both in terms of tariff and non-tariff barriers). The efficiency and cost competitiveness in this sector depends on factors such as scale of economy and capacity utilization. The capacity utilisation of the existing units may be enhanced by exploring under-utilized or unutilized oil seeds for production of oil. These include mahua, sal seed, grape seed, wild apricot and niger seed. The utilisation is dependent on availability of these seeds in different locations. Micro algae can also be explored for production of edible oil.

3.5 Major energy consuming areas (segment-wise)

Refining is an energy intensive process in vegetable oil process industries. Crude oil obtained from expellers and solvent extraction plant contains foreign impurities such as mucilage, gums, colours and unfiltered proteinous matter from seed. Refining is the process of removing undesired impurities such as unwanted moisture, FFA, gums, waxes, traces of metals, colouring components, odours and volatile components. A vegetable oil refinery has various sections such as degumming, neutralization, bleaching, deodorization and hydrogenation. The energy intensive processes in a refinery are as follows.

3.5.1 Degumming

Degumming is an essential step of the vegetable oil refining and it removes phosphor-lipids and other polar hydratable lipids. About 4-5% of the total generated steam is used in the degumming section at 3-4 kg/ cm^2 steam pressure to heat the oil to about 90-95^{0}C. Hot water (about 90^{0}C) is sprayed into the oil to help in removal of water-binding phospholipids.

3.5.2 Bleaching

The crude neutralised oil from the slurry tank is transferred into the bleaching vessel and vacuum is applied to suck the slurry while it is heated to a temperature of about 110^{0}C. The steam consumption for neutralization and the bleaching section accounts for about 38-45% of total steam generation.

3.5.3 Deodorization

The deodorization process is the major energy intensive process. The bleached oil is pumped to a primary heating plate heat exchanger (heated by outgoing hot refined oil), which is used only in a start-up condition. It is further heated to about 220-240^{0}C in a heat exchanger by using thermic fluid / thermo siphon. A 3-5 torr vacuum is maintained by using steam jet ejectors. The steam consumption for deodorization section accounts for about 50-55% of total steam generation.

3.5.4 Utilities

The utilities used in refinery plants are steam and thermic fluid/ Thermo siphon, electricity, cooling water system, chilled water system, compressed air, etc. In a refinery plant a number of cooling towers are used for vacuum generation and process cooling. The total cooling water system load is around 20-25% of the total power consumption. Chilled water is used in the fractionation section for separation of wax. The chilled water system load is 10-15% of the total power consumption. Compressed air is used for process and instrumentation purpose and its consumption is around 10-12% of the total load.

3.6 Energy saving potential and major areas

The capacity utilisation of the refineries is around 35% and the plants are designed based on the full capacity operation. Indian oil mills offer good potential for improvements through higher capacity utilisation of the units and energy efficiency improvements of various utilities. In an Indian oil mill, the wastage of energy was observed to be due to:

- Lower boiler efficiency due to part load operation
- Higher electricity consumption due to mismatching of cooling water pump
- Higher cost of energy by using diesel in thermic fluid heater
- Supply of low pressure steam in steam deodorizer
- Heat losses from poorly insulated or non-insulated steam lines, flanges and valves
- By-passing of steam traps leading to steam loss
- Hexane losses due to poor steam distribution and utilization.

Hence there is a significant scope for improving the energy efficiency in the refinery section by optimising the various energy intensive process equipment.

(Source: The Edible Oil and Ghee Sector, Environmental Report, April 1999; National Productivity Council (NPC), 2002, Environment Management Group, Sustainable Growth through Green Productivity – A Case of Edible Oil Industry in India, New Delhi, India)

4.0 Analysis of energy consumption data

4.1 Methodology

The purpose of the sectoral report is to understand the energy intensity of vegetable oil subsector, technology adopted and existing energy efficiency levels. It provides an overall energy scenario about the subsector. The report also assesses the potential for energy saving across the subsector. The methodology used for analysis of the energy consumption data and preparing the overview of the sectoral report is as follows.

- Secondary information collected from the public domain. Information and data were also collected based on interactions with industrial associations of the subsector such as Solvent Extraction Association (SEA) and Oil Technologists' Association of India (OTAI).

- The energy details of the industries have been taken from the annual reports of the respective industries. The details obtained of various units from their respective sources were then converted to tonnes of oil equivalent per tonne of product and analysed in accordance to its applicability for considering under PAT Scheme.

In order to calculate the energy consumption in terms of MTOE of individual units the following method has been used:

Electrical energy Total electrical energy (kCal)	:	$\boldsymbol{Total\ electricity\ consumed\ (kWh) x\ 860}$
Thermal Energy Total Thermal Energy (kCal)	:	$Fuel\ consumed\ (kg) x\ GCV\ (\frac{kCal}{kg})$
Specific electrical energy consumed per annum (SEC)	:	$\frac{Total\ electricity\ (kWh)}{Production\ during\ corresponding\ period}$
Specific thermal energy consumed per Annum (SEC)	:	$\frac{Total\ thermal\ energy\ (kCal)}{Production\ during\ corresponding\ period}$
Total energy consumed for each plant (Mtoe)	:	$\frac{Total\ electrical\ energy\ (kCal) + Total\ thermal\ energy (kCal)}{10{,}000{,}000}$

The conversion factors and values used for the conversion are as follows:

1 kWh	:	860 kCal
1 kCal	:	10^{-7}Mtoe
GCV of coal	:	3,000 kcal/ kg
GCV of diesel	:	9,600 kcal/ kg
GCV of furnace oil	:	10,000 kcal/ kg
GCV of husk	:	2,500 kcal/ kg

4.2 Plotting plant vs energy consumption (Mtoe)

The energy consumption details of the major industries (i.e. Adani Wilmar, Ruchi soya, Marico, Vimal oil, K. S. Oil and Sanwaria) were studied. Specific energy consumption (SEC) of vegetable oil unit is greatly influenced by factors such as raw material type, type of edible oil production, capacity utilisation, by-products, types of energy used.

The energy consumption for the year 2008-09, 2009-10 and 2010-11 of major vegetable oil industries including its various units and its production details are given in Tables 4.2a to 4.2f (Source: CMIE database).

Table 4.2a: Energy consumption details of Adani Wilmar Limited

Particulars	Unit	2008-09	2009-10	2010-11
Capacity	tonne/ year	10,76,550	12,29,250	19,13,800
Production	tonne/ year	7,96,216	9,41,483	10,72,111
Capacity utilisation	%	73.96	76.59	56.02
Thermal energy	10^6xMCal/ year	94.9	107.8	118.6
Electrical energy	10^6xMCal/ year	44	46	51
Total energy	10^6xMCal/ year	138.9	153.8	169.6
	Mtoe/ year	13,890	15,396	16,992

Table 4.2b: Energy consumption details of Ruchi Soya Industries Limited

Particulars	Unit	2008-09	2009-10	2010-11
Capacity	tonne/ year	22,11,000	22,71,000	22,71,000
Production	tonne/ year	14,63,903	16,64,189	19,43,068
Capacity utilisation	%	66.21	73.28	85.56
Thermal energy	10^6xMCal/ year	97.83	95.35	103.25
Electrical energy	10^6xMCal/ year	102.5	114.3	145.4
Total energy	10^6xMCal/ year	200.33	209.65	248.65
	Mtoe/ year	20,033	20,965	24,865

Table 4.2c: Energy consumption details of Marico Ltd

Particulars	Unit	2008-09	2009-10	2010-11
Capacity	tonne/ year	1,70,000	1,70,000	2,80,000
Production	tonne/ year	1,14,716	1,17,487	1,25,692
Capacity utilisation	%	67.48	69.11	44.89
Thermal energy	10^6xMCal/ year	11	11	36
Electrical energy	10^6xMCal/ year	12	12	14
Total energy	10^6xMCal/ year	23	23	50
	Mtoe/ year	2,265	2,298	4,964

Table 4.2d: Energy consumption details of Vimal oil

Particulars	Unit	2007-08	2008-09	2009-10	2010-11
Capacity	tonne/ year	74,997	75,004	74,996	75,000
Production	tonne/ year	62,870	47,050	52,910	1,01,010
Capacity utilisation	%	83.83	62.73	70.55	134.68
Thermal energy	10^6xMCal/ year	64.18	19.54	19.16	31.97
Electrical energy	10^6xMCal/ year	1.38	1.31	1.45	2.86
Total energy	10^6xMCal/ year	65.56	20.85	20.61	34.83
	Mtoe/ year	6,556	2,085	2061	3,483

Table 4.2e: Energy consumption details of K. S. Oil

Particulars	Unit	2007-08	2008-09	2009-10	2010-11
Capacity	tonne/ year	1,65,000	3,90,000	5,10,000	6,00,000
Production	tonne/ year	2,11,464	2,21,676	4,03,563	4,77,000
Capacity utilisation	%	128.16	56.84	79.13	79.5
Thermal energy	10^6xMCal/ year	12.74	13.04	21.59	21.29
Electrical energy	10^6xMCal/ year	26.39	31.22	43.87	34.21
Total energy	10^6xMCal/ year	39.13	44.26	65.46	55.5
	Mtoe/ year	3,914	4,426	6,546	5,549

Table 4.2f: Energy consumption details of Sanwaria agro oil

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
Capacity	tonne/ year	54,750	91,250	91,250	91,250
Production	tonne/ year	36,690	30,730	27,700	33,090
Capacity utilisation	%	67	34	30	36
Thermal energy	10^6xMCal/ year	13	12	11	12
Electrical energy	10^6xMCal/ year	1.1	1.1	1.1	1.3
Total energy	10^6xMCal/ year	14	13	12	13
	Mtoe/ year	1,430	1,306	1,188	1,321

The detailed calculations of each industry are given in **Appendix 4/1.**

The production and energy consumption details given in Tables 4.2a to 4.2f are based on the entire group rather than individual unit. Hence it may not be possible to estimate the total energy consumption per plant. A summary of the major vegetable oil industries for 2010-11 is given in Table 4.2g.

Table 4.2g: Specific energy consumption details of major vegetable oil industries

Particulars	Unit	Adani Wilmar	Ruchi Soya	Marico Ltd	Vimal Oil	K S Oil	Sanwaria Agro
Capacity	tonne/ year	19,13,800	22,71,000	2,80,000	75,000	6,00,000	91250
Production	tonne/ year	10,72,111	19,43,068	1,25,692	1,01,010	4,77,000	33,090
Capacity utilisation	%	56.02	85.56	44.89	134.68	79.5	36
Total energy	10^6xMCal/ year	169.6	248.65	50	34.83	55.5	13
	Mtoe/ year	16,992	24,865	4,964	3,483	5,549	1,321
Specific energy consumption	Mtoe/ tonne	0.02	0.01	0.04	0.03	0.01	0.04

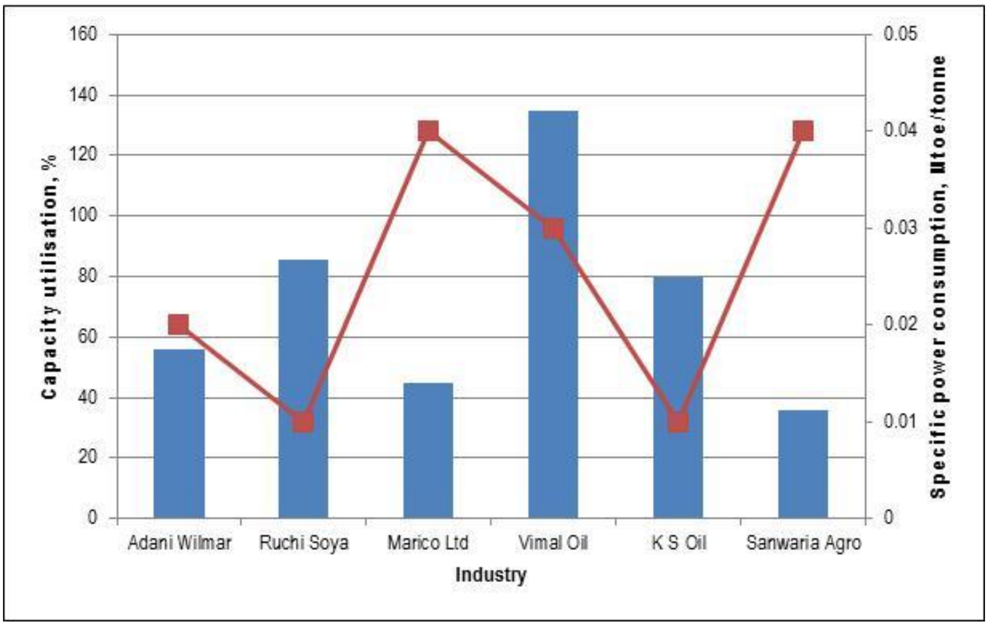

Figure 4.2: Specific energy consumption details of major vegetable oil industries

It can be seen that the specific energy consumption of the refinery is around 0. 01 Mtoe/ tonne to 0.04 Mtoe/ tonne. The specific power consumption of the refinery plant is majorly depends on the capacity utilisation. In 2011, the production by these six industries was around 3.75 million tonne which was around 50% of the net vegetable oil domestically available (7.63million tonne) as providing in table 2.5. Also, discussions were held with members of the Solvent Extraction Association (SEA) on the capacity of vegetable oil industries in India and their energy consumption. The specific energy consumption of the vegetable oil sector was evaluated based on these inputs for different capacities and is given in Table 4.2h and 4.2i.

Table 4.2h: Specific energy consumption of vegetable oil refineries

Particular	Unit	100 TPD plant	500 TPD plant	1000 TPD plant
Electricity consumption	kWh/ tonne	40	36	34
	MCal/ tonne	34.4	30.96	29.24
Coal for steam generation	kg/ tonne	70	63	60
Coal for high temp deodorisation	kg/ tonne	10	9	8.5
	MCal/ tonne	240	216	205.5
Energy consumption	Mtoe/ year	1,002	4,500	8,568
Specific energy consumption	MCal/ tonne	274.4	246.96	234.74
	Mtoe/ tonne	0.03	0.02	0.02

The total annual energy consumption of the refinery is vary from 1,000 Mtoe to 8,570 Mtoe. The SECs of solvent extraction plant and crushing unit is around 0.01 Mtoe per tonne and 0.005 Mtoe per tonne respectively. Based on the plant capacity and utilization factor, the specific energy consumption and total energy was evaluated for the vegetable oil sector (excluding vanaspati plant), Table 4.2i.

Table 4.2i: Energy consumption of vegetable oil processing unit

Description	Unit	Crushing unit	Solvent extraction	Refineries
Number of plants		1,50,000	810	1,060
Capacity	million MT/ year	45	35	13.8
% of utilization	%	20	31	35
Total energy consumption	Mtoe/ year	45,000	1,08,500	1,20,750
Specific energy consumption	Mtoe/ tonne	0.051	0.01	0.025

The total energy consumption of the vegetable oil sector is estimated to be 0.274mMtoe. The energy consumption for crushing, solvent extraction and refineries is given in Table 4.2j. From the above table it can be observed that energy consumption of vegetable oil refinery is 1,20,750 Mtoe which is high as compare to Solvent extraction units (1,08,500 Mtoe).

Table 4.2j: Total energy consumption of vegetable oil sector

Sector	Energy consumption (Mtoe)
Crushing unit	45,000
Solvent extraction	1,08,500
Refineries	1,20,750
Total	**2,74,250**

Note: Vanaspati plant is excluded which is separate from refineries

4.3 Possible EE measures for the sub-sectors

Vegetable oil refineries are more energy intensive as compared to others such as crushing and solvent extraction units. Some of the energy efficiency measures that are applicable for vegetables oil refineries are provided below.

4.3.1 Steam generation and distribution system

About 70-80% of coal is used for steam generation and the remaining 20-30% is used for thermic fluid heating / thermo siphon in a refinery plant. Steam is used in various sections such as degumming, neutralization, bleaching, deodorization and tank farm heating. The potential energy conservation measures are provided below:

- Condensates from all the sections of the plant can be recovered and used as feed water to the boiler.
- High pressure steam with 10-12 kg/ cm2 is used in neutralization, bleaching section, etc. There is a potential to recover the flash steam from the high pressure condensate and use the low pressure flash steam for oil heating in the tank farm section.

4.3.2 Pumping system

In a refinery plant pumps are used for transferring of crude vegetable oil, cooling water and chilled water circulation. The cooling water system load is around 30-35% of the total power consumption of the plant. The pumping system of the plant is designed based on the capacity of the plant. However, the plant uses only 35 % of the designed capacity leading to reduced efficiencies. The potential energy conservation measures that can be followed are as follows.

- Avoiding throttling and replacing high capacity pumps with small capacity pumps
- Installing variable speed drive (VSD) so that based on the plant load the pumps can be operated at lower frequency.

4.3.3 Chilled water generation system

Chilled water is use in vegetable oil refinery for fractionation process. The average power consumption of chilled water system is around 10-12% of the total power consumption of the plant. However, the low capacity utilisation (about 35%) has led to inefficiencies and higher energy consumption. The potential energy conservation measures in chilled water system are given below.

- Avoiding bypass flows by closing valves of standby equipment
- Avoiding the mixing of supply and return chilled water.
- Set the chiller evaporator temperature based on the process requirement.
- Minimizing part load operations by matching loads and plant capacity on line; adopting VSDs for varying process load.
- Making efforts to continuously optimize condenser and evaporator.
- Avoiding loss in chilled water distribution system using adequate thickness of insulation.

The estimated energy saving potential in the vegetable oil refineries is around 5-8%. This offers a potential of saving about 500 mtoe (metric tonne of oil equivalent) per year.

4.4 Conclusions and recommendations

The vegetable oil refinery industry is the largest energy user in the vegetable oil processing sector as compared to crushing and solvent extraction industries. There are about 1,060 vegetable oil refineries operating in India, most of which are of small scale type with capacities ranging from 5 tpd to 100 tpd. There are 13 major vegetable oil refineries with capacities ranging from 300 tpd to 1000 tpd. These 13 major refineries account for about 70-75% of vegetable oil processing in India. The total energy consumption of these major oil refineries is estimated to be in the range of 80,000 to 90,000 Mtoe per year which is quite significant.

The capacity utilisation of major vegetable oil refineries is about 35 to 40% which is low. There are significant opportunities available to these refineries for utilizing effectively the existing capacities either through enhancing the availability of oil seeds at domestic level or through crude oil imports for further processing. The energy consumption levels of the vegetable oil refineries were also found to be higher. The high energy consumption of refineries depends on various factors such as (1) type of oilseed being processed (palm oil and sunflower oil require winterisation for separation of wax), (2) low capacity utilization and (3) types of fuels used. Various studies in India as well as other countries show that there is significant potential for energy efficiency improvements. There exists an energy saving potential of 5% to 8% in major oil refineries operating in India. It may be concluded that future interventions in vegetable oil sector must focus on major oil refineries to achieve higher energy savings in the sector.

Major vegetable oil refinery per year energy consumption and threshold limits for vegetable oil refinery is shown in figure 4.4.

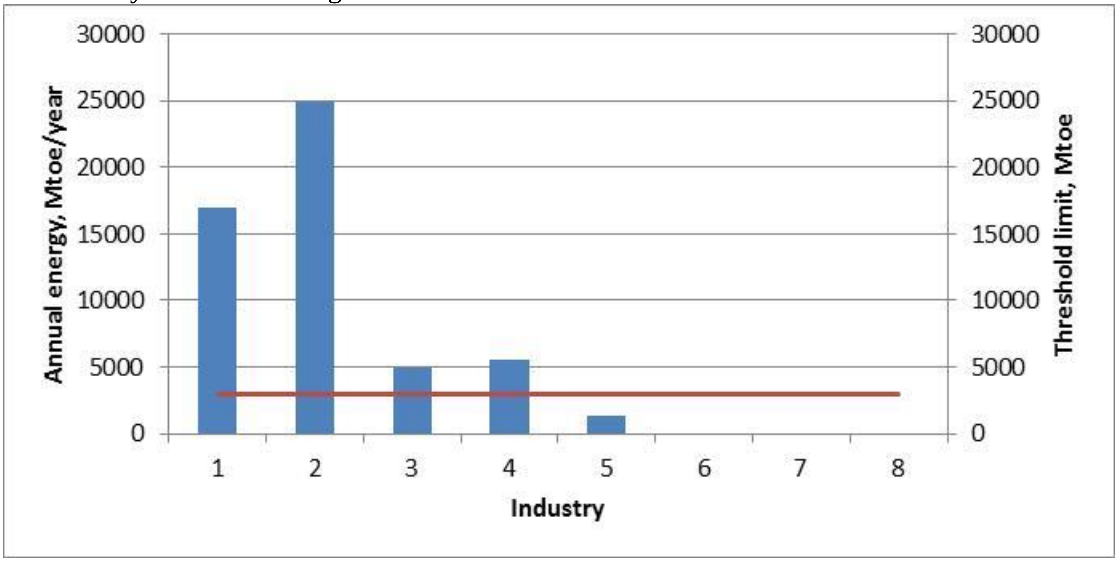

Figure 4.4: Annual energy consumption and threshold limit for vegetable oil refinery

*for other major industries data is not available

It can be seen that annual energy consumption (Mtoe) of different vegetable oil refinery is vary based on plant capacity and utilisation factor. The total energy consumption of four industries above threshold limits around 52000 Mtoe per year which is 43 percent of total vegetable oil refinery energy consumption.

It is recommended that the vegetable oil refinery industry may be considered to be included as 'Designated Consumers' (DCs). A threshold limit of 3,000 Mtoe may be considered for vegetable refinery industries for including them as DCs. This is equal to the threshold limit for textile industries. By considering a threshold limit of 3,000 Mtoe, about eight numbers of major refineries would get included as DCs under PAT.

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Appendices

Appendix 2.1

World oilseed production and yield

Country	Production (mMt)	Area under cultivation (Million hectare)	Yield (Mt/ ha)
U.S.A	90.97	35.16	2.59
Brazil	70.11	27	2.6
China	50.87	25.83	1.97
Argentina	45.46	20.14	2.26
India	**35.07**	**41.11**	**0.85**
C.I.S.	30.66	21.53	1.42
EU-27	29.38	11.84	2.48
Other countries	29.36	36.63	0.8
Canada	19.13	9.3	2.06
Indonesia	9.2	10.64	0.86
Pakistan	5.33	3.69	1.44
Australia	4.87	2.54	1.92
Malaysia	4.7	4.58	1.03
Paraguay	4.53	3.16	1.43
Turkey	2.28	1.07	2.13
Philippines	2.05	2.43	0.84
Other Europe	1.27	0.5	2.54

Appendix 2.2

Imports of edible oils

Year	Refined oil												Crude oil	Total Import
	RBD Palmolein	Ref. Sunflower oil	Ref. Rapeseed oil	Ref. Soybean oil	Palm oil	Olein	Sunflower oil	Soybean oil	Rapeseed (degummed)	Cotton oil	Coconut oil	Palm Ker. Oil	Safflower oil	
	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt	Mt
1996-97	12,29,223						4,10,325	46,455	27,203	36,920				1750126
1997-98	14,69,724		29,754	85,017			1,76,159	2,16,440	66,625	39,572	252			2083543
1998-99	26,76,712	7,500	82,659	2,46,624			5,45,006	6,26,758	1,71,954	32,208	4,000			4393421
1999-00	22,13,777		6,320	19,000	8,28,359		5,73,388	6,87,379	1,00,569	64,061	1,700			4494553
2000-01	15,16,688			7,000	14,04,723	32,877	3,87,761	14,14,937	35,969	31,450	2,403			4833808
2001-02	1,18,895			3,499	18,91,538	9,20,015	2,800	14,75,531	10,400		2,504			4425182
2002-03	3,19,379			28,994	21,51,294	12,61,568	94,600	11,67,723	5,540		7,701	77,650		5114449
2003-04	7,96,846			15,324	20,59,579	4,91,943	75,822	8,90,695			2,029	64,349		4396587
2004-05	4,22,735			25,003	23,60,573	1,86,684	5,018	20,01,745			7,291	32,558		5041607
2005-06	1,13,491	1,050		20,457	23,72,681	55,804	1,00,843	17,03,360			22,307	26,840		4416833
2006-07	1,15,142			11,120	29,94,225	53,440	1,95,245	13,22,920			12,996	9,672		4714760
2007-08	7,30,794				40,44,063	8,350	26,490	7,59,433			13,016	26,264		5608410
2008-09	12,40,018				51,87,063	745	5,90,175	9,89,613	46,362	5,069	16,693	1,07,622		8183360
2009-10	12,13,409				51,69,445	4,428	6,30,005	16,66,492	13,950	9,438	4,198	1,11,973		8823338
2010-11	10,81,686				53,74,333	6,501	8,03,593	10,06,691	11,122		2,967	84,566		8371459
2011-12*	13,25,163				38,82,383	500	9,00,281	8,17,212	90,758		1,999	80,971	5400	7104667

Source : SEA Annual report

*up to July

Appendix 2.3

Oilseed production in India

Oilseed	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Soybean	5.28	5.93	4.65	7.82	6.87	8.27	8.85	10.97	9.9	9.97	12.66	12.28
Rapeseed (mustard)	4.19	5.08	3.88	6.29	7.59	8.13	7.44	5.83	7.2	6.61	7.67	6.78
Groundnut	6.41	7.03	4.12	8.13	6.77	7.99	4.86	9.18	7.17	5.43	7.54	6.93
Castor	0.88	0.65	0.43	0.8	0.79	0.99	0.76	1.05	1.17	1.01	1.34	2.31
Sesame	0.52	0.7	0.44	0.78	0.67	0.64	0.62	0.76	0.64	0.59	0.88	0.73
Sunflower	0.65	0.68	0.87	0.93	1.19	1.44	1.23	1.46	1.16	0.85	0.62	0.54
Safflower	0.2	0.22	0.18	0.13	0.17	0.23	0.24	0.22	0.19	0.18	0.14	0.09
Linseed	0.2	0.21	0.18	0.2	0.17	0.17	0.17	0.16	0.17	0.15	0.14	0.14
Niger	0.11	0.13	0.09	0.11	0.11	0.11	0.12	0.11	0.12	0.1	0.12	0.1

Appendix 3.1

Detail process description of vegetable oil sector

Process description

The Indian edible oil industry can be classified into four part expellers / Ghanis, solvent extractors, oil refiners and vanaspati manufacturers.

1 Expeller /Ghani

A ghani (also known as a 'chekku' or 'kol') is a mortar and pestle device which grinds oilseed into fine particles and extracts the oil from it. The mortar is fixed to the floor and is normally made from wood. The pestle can be made from either wood or stone. Usually the power source is a bullock harnessed to a long lever arranged to turn the pestle inside the mortar. Batch of oilseed is loaded into the mortar. As the bullock moves the lever around the mortar, the pestle grinds the oilseed inside. After the seed has been ground, a certain amount of water is added. The water combines with the ground oilseed, releasing oil which is expelled by the kneading action of the pestle through a hole in the bottom of the mortar; the oil is collected in a container. When the ghani operator is satisfied that a good yield of oil has been extracted from the seed, the ghani is brought to a halt and the oil-cake is removed. Another batch of seed is placed in the mortar and the process is repeated. A typical bullock-driven ghani can process about 10 kg seed every 2 h. The bullock normally becomes fatigued after working the ghani for about 3-4 h and is replaced by another one.

Electrically-powered ghanis, known in India as 'power ghanis', are now replacing bullock-driven ghanis because bullocks are becoming increasingly costly to maintain. Either the pestle or the mortar is held stationary in power ghanis (see Figures 1 and 2) which are normally run in pairs so that one is always operating while the other is being discharged. About 100 kg seed/ day is the usual throughput.

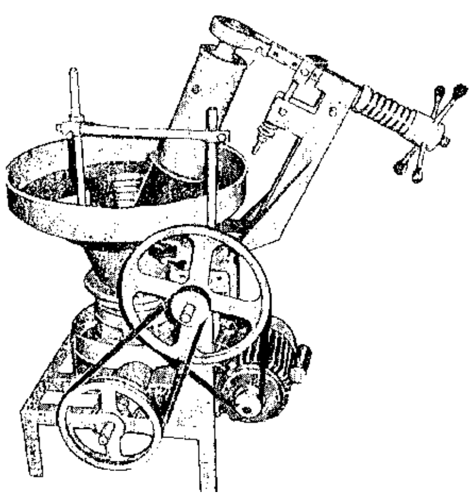

Figure 1 Power ghani with stationary pestle

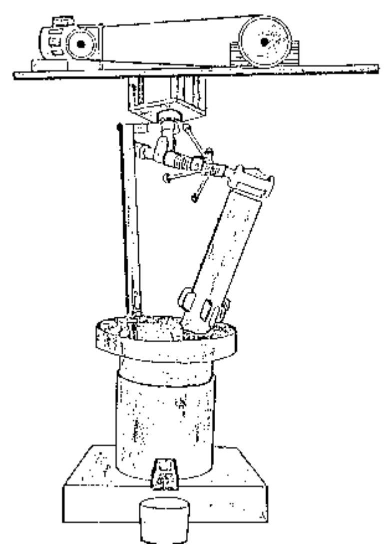

Figure 2 Power ghani with stationary mortar

The advantages of the ghani are that it produces a reasonable oil yield of about 60%, it can be made locally, and it has low running costs. Oil produced in a ghani is usually valued for its quality. In addition, no pre-grinding equipment is needed for smaller oilseeds such as groundnuts, rapeseed, sesame and sunflower seeds, and it is suitable for use by small groups in villages.

Expellers

Oilseed expellers produce oil and oil-cake from oilseed continuously, unlike bridge presses which operate on a batch system. The essential components of a typical small-scale expeller are shown in Figure 3. The expeller is driven either by an electric motor or by a diesel engine. At the heart of the machine is a powered worm shaft which rotates inside a closely fitting cage. The oilseed is fed continuously into the press through a hopper and is crushed as it is transported through the cage by the worm shaft. Pressure is exerted on the system by restricting the gap at the end of the cage through which the oil cake is discharged from the press. The expelled oil drains out of the cage through small gaps.

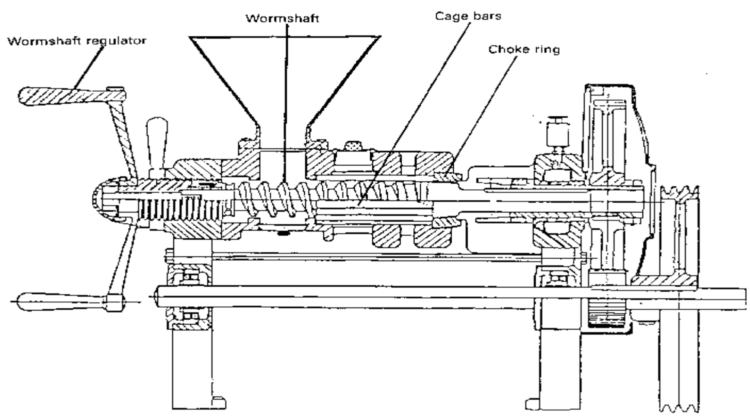

Figure 3 Outline drawing of a typical small-scale expeller

The friction generated inside the expeller barrel will eventually result in the wearing down of the worm shaft end portion, barrel bars or rings, and choke. Replacement of these parts will be required at intervals depending on the type and amount of oilseed processed and the degree of dirt contaminating the seed. Rapid wear is a particular problem when expelling undecorticated, dirty sunflower seed. The availability and cost of wearing parts are important considerations when setting up a small-scale expeller facility.

2 Solvent extraction

The cracked beans/ oil cake are conveyed to the conditioning area, where they are put either into a rotary steam tubed device or into a stacked cooker and are heated to "condition" them(i. e., make them pliable and keep them hydrated). Conditioning is necessary to permit the flaking of the chips and to prevent their being broken into smaller particles. Finally, the heated, cracked beans/ oil cake are conveyed and fed to smooth, cylindrical rolls that press the particles into smooth "flakes", which vary in thickness from approximately 0.25 to 0.51 millimetres (0.010 to 0.020 inches).

Solvent extraction and 0il desolventizing

The extraction process consists of "washing" the oil from the bean / oil cake flakes with hexane solvent in a counter current extractor. Then the solvent is evaporated (i. e., desolventized) from both solvent/ oil mixture (micella) and the solvent-laden, defatted. The oil is desolventized by exposing the solvent/ oil mixture to steam (contact and noncontact). Then the solvent is condensed, separated from the steam condensate, and reused. Residual hexane not condensed is removed with mineral oil scrubbers. The desolventized oil, called "crude" oil, is stored for further processing or load out.

Desolventizing flakes

The flakes leaving the extractor contain up to 35 to 40 % solvent and must be desolventized before use. Flakes are desolventized in one of two ways: either "conventional" desolventizing or specialty or "flash" desolventizing. The method used depends upon the end use of the flakes. Flakes that are flash desolventized are typically used for human foods, while conventionally desolventized flakes are used primarily in animal feeds. Conventional desolventizing takes place in a desolventizer-toaster (DT), where both contact and noncontact steam are used to evaporate the hexane. In addition, the contact steam "toasts" the flakes, making them more usable for animal feeds. The desolventized and toasted flakes then pass to a dryer, where excess moisture is removed by heat, and then to a cooler, where ambient air is used to reduce the temperature of the dried flakes. The desolventized, defatted flakes are then ground for use as soybean meal

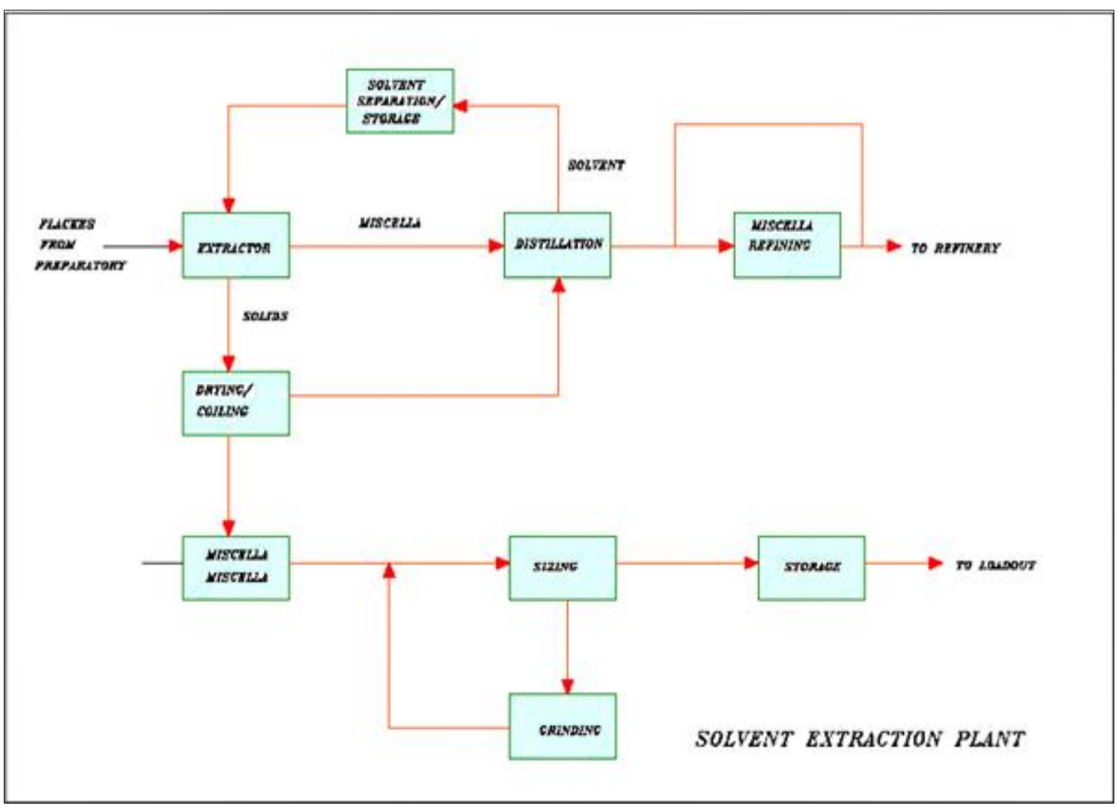

Figure 4 Flow diagram of solvent extraction process

3 Refinery

The crude oil is refined to remove undesired impurities such as gums, free fatty acids (FFA), traces of metals, colouring components, and volatile components. During refining, the FFA is removed to the level of less than 0.1 percent in the refined oil either by chemical or physical refining. Where appropriate, preference should be given to physical rather than chemical refining of crude oil as the bleaching earth used in this process has a lower environmental impact. Conversely, chemical refining results in a better product quality in terms of lower FFA levels, longer shelf life, and a more reliable process. Before refining occurs, degumming may be applied to the crude oil.

Degumming is an essential step of the physical refining process because the oil entering the final deodorization has to have a low content of phosphatide. Degumming is also used in conjunction with chemical refining. Degumming methods can either be acidic or enzymatic. In acidic degumming, phosphoric acid is added to remove phosphatides, phospholipids, and lecithins. Citric acid is also used instead of phosphoric acid, which brings a range of advantages, including reduced phosphorus load in the wastewater and a slight reduction in the amount of sludge. Enzymatic degumming uses enzymatic hydrolysis of the phosphatides. Environmental benefits from this approach include reduced consumption of phosphoric and sulphuric acid, as well as caustic soda, water, and energy.

Chemical refining

Conventional chemical refining involves degumming for the removal of phospholipids, neutralization for the removal of FFA, and bleaching for decolourization and deodorization. Water is added during degumming to hydrate any gums present and the mixture is then centrifuged for separation. Non-hydratable gums are removed using phosphoric or citric acid before water is added and separation takes place in a centrifuge.

During degumming, caustic soda is added to the oil, which has been preheated to between 75°C and 110°C to saponify the FFA. This process gives rise to two main outputs, namely semi-refined oil and soap stock. The soap stock is removed by precipitation followed by sedimentation or centrifugation and may be further processed into acid oils by splitting. The soap stock is heated to between 70°C and 100°C and reacts with sulphuric acid to reform the fatty acids. The resulting by-products can be sold to the paints and cosmetics sector, as well as to the animal feed industry. The neutralized oil is bleached to remove colouring matter and other minor constituents.

Physical refining

Physical refining is a more simple process in which the crude oil is degummed and bleached, and then steam stripped to remove FFA, odour, and VOCs all in one step. A physical pre-treatment can be used to achieve low phospholipid content by degumming and using bleaching earth. Following this, FFA can be stripped from the physically pre-treated oil using steam in a vacuum at temperatures of around 250°C and refined by the oil flowing over a series of trays counter current to the flow of the stripping steam. A scrubber is then used to condense the greater part of the fat from the vapours as a water-free product.

Winterisation process is applied specially to sunflower oil with lower wax content. The bleached oil is cooled through oil-to-oil heat exchanger and then pumped into crystallizer where small amount of the filter aid like ELITE is dosed. The oil is continuously kept at low temperature which aids crystallization of waxes. The crystallized oil is then fed to a maturator for further improvement of the wax crystals. The oil is the pumped into a pressure leaf filter where the filter aid retains the wax and clear de-waxed oil is produced.

4 Vanaspatti (Hydrogenation)

Oils may be partially hydrogenated to produce various ingredient oils. Lightly hydrogenated oils have very similar physical characteristics to regular soy oil, but are more resistant to becoming rancid. Margarine oils need to be mostly solid at 32 ºC (90 °F) so that the margarine does not melt in warm rooms, yet it needs to be completely liquid at 37 °ºC (98 °F), so that it doesn't leave a "lardy" taste in the mouth.

Hardening vegetable oil is done by raising a blend of vegetable oil and a catalyst in near-vacuum to very high temperatures, and introducing hydrogen. This causes the carbon atoms of the oil to break double-bonds with other carbons, each carbon forming a new single-bond with a hydrogen atom. Adding these hydrogen atoms to the oil makes it more solid, raises the smoke point, and makes the oil more stable.

Hydrogenated vegetable oils differ in two major ways from other oils which are equally saturated. During hydrogenation, it is easier for hydrogen to come into contact with the fatty acids on the end of the triglyceride, and less easy for them to come into contact with the centre fatty acid. This makes the resulting fat more brittle than a tropical oil; soy margarines are less "spreadable". The other difference is that trans fatty acids (often called trans-fat) are formed in the hydrogenation reactor, and may amount to as much as 40 percent by weight of partially hydrogenated oil. Hydrogenated oils, especially partially hydrogenated oils with their higher amounts of trans fatty acids are increasingly thought to be unhealthy.

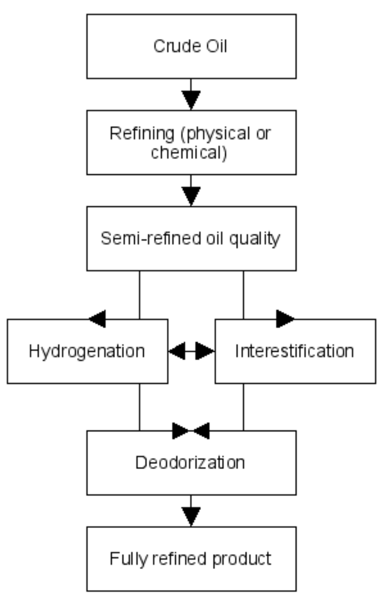

Figure 4 Flow diagram of refinery

Appendix 3.2

Specific energy consumption of a typical refinery unit

Particulars	Unit	2005-06	2006-07	2007-08
Capacity of the plant	TPD	1,000	1,000	1,000
Total production	MT	1,12,295	1,27,399	1,89,910
Capacity utilization	%	31	35	52
Electricity consumption	kWh	62,78,000	88,57,000	95,55,000
	mtoe	539.908	761.702	821.73
Thermal energy consumption	M kCal	31,779	34,016	40,451
	Mtoe	3,178	3,402	4,045
Total energy consumption	Mtoe	3,718	4,163	4,867
Specific electricity consumption	kWh/ ton	55.91	69.52	50.31
	kCal/ ton	48,079	59,789	43,269
Specific thermal energy consumption	kCal/ ton	2,82,996	2,67,004	2,13,001
Share of electricity consumption	%	15	18	17
Share of thermal energy consumption	%	85	82	83
Total energy cost	lakh Rs	406.49	559.21	694.67
Manufacturing cost	lakh Rs	46,203	52,053	80,340
Share of energy cost	%	0.88	1.07	0.86
Total sp energy consumption	kCal/ ton	3,31,075	3,26,792	2,56,270

Appendix 4.1

Energy consumption of major vegetable oil processing units in India

Adani Wilmar Limited

Particulars	Unit	Mar-09	Mar-10	Mar-11
Capacity	tonne	10,76,550	12,29,250	19,13,800
Capacity utilisation	%	73.96	76.59	56.02
Production	tonne	7,96,216	9,41,483	10,72,111
energy				
Coal	tonne/ tonne	0.013	0.01	0.01
	tonne	10,351	9,415	10,721
	MCal/ year	3,10,52,439	2,82,44,477	3,21,63,323
Furnace Oil	tonne/ tonne	0.0038	0.0040	0.0036
	tonne	3002	3,719	3,817
	MCal/ year	3,00,17,357.53	3,71,88,561.71	3,81,67,143.06
Husk	tonne/ tonne	0.017	0.018	0.018
	tonne	13,536	16,947	19,298
	MCal/ year	3,38,39,196	4,23,66,716	4,82,44,984
Total Thermal energy	MCal/ year	9,49,08,992	10,77,99,755	11,85,75,450
	MCal/ tonne	119	115	111
	Mtoe/ year	9,491	10,780	11,858
Sp thermal power	Mtoe/ tonne	0.01	0.01	0.01
Electricity	kWh/ tonne	64.25	57.01	55.69
	kWh	5,11,56,902	5,36,73,922	5,97,05,848
	MCal/ year	4,39,94,936	4,61,59,573	5,13,47,029
	Mtoe/ year	4,399	4,616	5,135
Total Energy	Mtoe/ year	13,890	15,396	16,992
Specific energy consumption	toe/ tonne	0.02	0.02	0.02

Ruchi Soya

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
Capacity	tonne	21,21,000	22,11,000	22,71,000	22,71,000
Utilisation	%	71.89	66.21	73.28	85.56
Production	tonne	15,24,787	14,63,903	16,64,189	19,43,068
Coal	tonne	26,615.16	23,594.20	26,225.61	29,168.60
	MCal	7,98,45,480	7,07,82,600	7,86,76,824	8,75,05,800
Electricity (purchased)	kWh	13,73,45,170	11,36,60,728	12,63,45,119	16,35,40,182
Electricity (through diesel generator)	kWh	56,25,727	55,30,875	65,27,807	55,11,279
Total electricity	kWh	14,29,70,897	11,91,91,603	13,28,72,926	1690,51,461
	kWh/ tonne	94	81	80	87
	MCal	12,29,54,972	10,25,04,779	11,42,70,716	14,53,84,256

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
High speed diesel	KL	2,456	3,315	2,044	1,930
	MCal	2,00,40,878	2,70,52,195	1,66,75,368	1,57,48,882
Thermal energy	Mcal	9,98,86,358	9,78,34,795	9,53,52,192	10,32,54,682
Total energy	MCal	22,28,41,330	20,03,39,574	20,96,22,908	24,86,38,938
	Mtoe	22,284	20,034	20,962	24,864
Sp energy	toe/ tonne	0.01	0.01	0.01	0.01

Marico Ltd.

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
Capacity	Tonne	1,70,000	1,70,000	1,70,000	2,80,000
Production	Tonne	1,07,916	1,14,716	1,17,487	1,25,692
Utilisation	%	63.48	67.48	69.11	44.89
Electricity	kWh/ tonne	122.17	119.09	117	127.86
	tonne/ year	1,31,84,098	1,36,61,528	1,37,45,979	1,60,70,979
	MCal/ year	1,13,38,324	1,17,48,914	11,821,542	1,38,21,042
Furnace oil	KL/ tonne	0.01	0.01	0.01	0.03
	KL/ year	1,079	1,147	1,175	3,771
	MCal/ year	1,02,52,020	1,08,98,020	1,11,61,265	3,58,22,220
Total	MkCal/ year	2,15,90,344	2,26,46,934	2,29,82,807	4,96,43,262
	toe/ year	2,159	2,265	2,298	4,964
Specific energy	Mtoe/ tonne	0.02	0.02	0.02	0.04

Vimal Oil

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
Capacity	tonne	74,997	75,004	74,996	75,000
Production	tonne	62,870	47,050	52,910	1,01,010
Utilisation	%	83.83	62.73	70.55	134.68
Diesel	tonne/ tonne	0.09	0.0277	0.023	0.026
	tonne/ year	5,658	1,303	1,217	2,626
	MCal/ year	5,65,83,000	1,30,32,850	1,21,69,300	2,62,62,600
Electricity	kWh/ tonne	25.6	32.47	31.88	32.98
	kWh/ year	16,09,472	15,27,713.5	16,86,770.8	33,31,309.8
	MCal/ year	13,84,146	13,13,834	14,50,623	28,64,926
Gas	SCM/ tonne	0.01632	0.01887	0.0183	0.00625
	SCM/ year	1,026	888	968	631
	MCal/ year	70,18,102.656	60,72,781.14	66,22,850.52	43,18,177.5
Lignite	tonne/ tonne	0.004	0.004	0.003	0.006
	tonne/ year	251	188	159	606
	MCal/ year	5,78,404	4,32,860	3,65,079	13,93,938
		6,41,79,506.66	1,95,38,491.14	1,91,57,229.52	3,19,74,715.5
Total energy	MCal/ year	6,55,63,653	2,08,52,325	2,06,07,852	3,48,39,642
	toe/ year	6,556	2,085	2,061	3,484
Sp energy	toe/ tonne	0.10	0.04	0.04	0.03

K S Oil

Particulars	Unit	Mar-07	Mar-08	Mar-09	Mar-10	Jun-11
Refined Oil capacity	tonne	1,20,000	1,65,000	3,90,000	5,10,000	6,00,000
Utilisation	%	94.7	128.16	56.84	79.13	79.5
Production	tonne	1,13,640	2,11,464	2,21,676	4,03,563	4,77,000
Coal	tonne/ year	2,352	4,250	4,346	7,198	7,097
	MCal/ year	70,55,280	1,27,49,130	1,30,37,220	2,15,94,510	2,12,90,700
Electricity (purchased)	kWh	67,62,457	1,52,24,175	1,59,82,597	3,02,02,237	1,90,63,573
Electricity (through diesel generator)	kWh	75,55,036	1,17,52,427	79,05,868	56,78,268	27,72,341
Electricity (through generator)	kWh	46,32,383	43,33,563	1,36,07,453	2,09,46,966	2,33,78,783
Total electricity	kWh	1,82,11,263	306,88,823	3,63,06,034	5,10,12,084	3,97,76,842
	kWh/ tonne	160.25	145.13	163.78	126.40	83.39
	MCal/ year	1,56,61,687	2,63,92,388	3,12,23,189	4,38,70,392	3,42,08,084
Total Energy	MkCal/ year	2,27,16,967	3,91,41,518	4,42,60,409	6,54,64,902	5,54,98,784
	Mtoe/ year	2,272	3,914	4,426	6,546	5,550
Sp energy	Mtoe/ tonne	0.02	0.02	0.02	0.02	0.01

Sanwaria Agro Oils Ltd

Particulars	Unit	Mar-08	Mar-09	Mar-10	Mar-11
Capacity	tonne	54,750	91,250	91,250	91,250
Production	tonne/ year	36,690	30,730	27,700	33,090
Utilisation	%	67	34	30	36
Coal	tonne/ tonne	0.12	0.13	0.13	0.12
	tonne/ year	4,403	3,995	3,601	3,971
	MkCal/ year	1,32,08,400	1,19,84,700	1,08,03,000	1,19,12,400
Electricity	kWh/ tonne	34.7	40.5	45.33	45.65
	kWhyear	12,73,143	12,44,565	12,55,641	15,10,559
	MkCal/ year	10,94,903	10,70,326	10,79,851	12,99,080
Total energy	MkCal/ year	1,43,03,303	1,30,55,026	1,18,82,851	1,32,11,480
	toe/ year	1,430	1,306	1,188	1,321
Sp energy	toe/ tonne	0.04	0.04	0.04	0.04

Appendix 4.2

Major vegetable oil industries

S No	Name of the industry	Capacity (tonne per day)
1	Adani Wilmar	9,000 (9 plants)
2	Ruchi	6,000
3	Marico	570
4	Cargill	4,851
5	K S Oil	1,644 (3 plants)
6	Anil Industries	700 (2 plants)
7	Gokul Refoils	1,000
8	Emami	3,300