EFFECTIVENESS OF INTRODUCING HIGH EFFICIENT MOTORS IN TEA PROCESSING MACHINERIES

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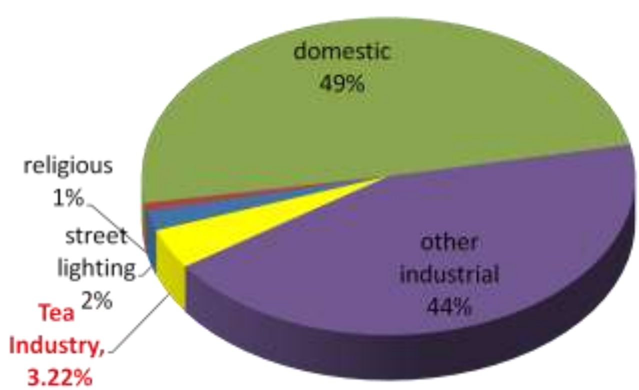
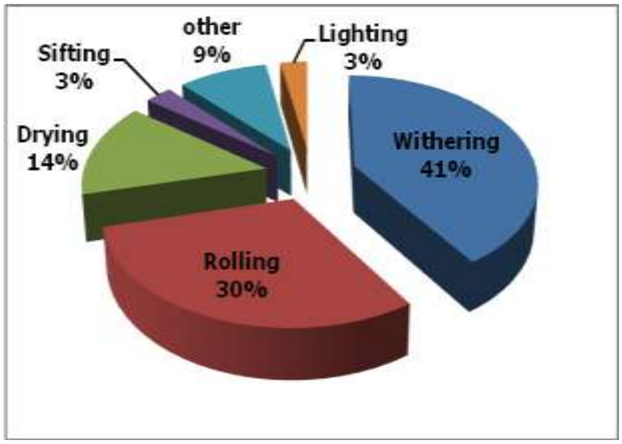
INTRODUCTION



Electricity Consumption in Sri Lanka (GWh/ Yr)
(Sri Lanka Energy Balance 2014, Sri Lanka Sustainable Energy Authority)

Electricity consumption is considerable
- potential for energy conservation



Typical energy balance in tea factory

(Energy Management Programme in Tea Sector, Sri Lanka Sustainable Energy Authority)

Withering & Rolling processes – High electrical energy consumption

Induction motors are widely used in machineries in tea factories.

Electrical energy consumption – higher than acceptable level

- Old, rewound, oversized
- Run at constant speed
- High power losses and low output

Motor Efficiency Classes

- IE1 (Standard Efficiency)
- IE2 (High Efficiency)
- IE3 (Premium Efficiency)
- IE4 (Super Premium Efficiency)

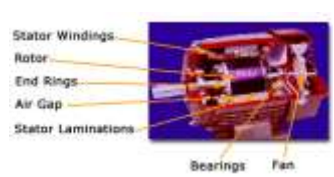
* *IE = International Efficiency*

The IE-code and its efficiency levels create a basic vocabulary for governments to determine the efficiency level for their minimum energy performance standards (MEPS).

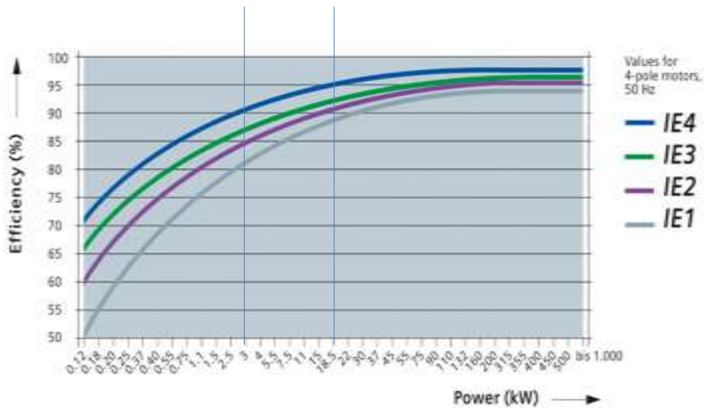
Premium Efficiency Motor

- Large diameter copper wire in the stator and more aluminum in the rotor reduce resistance losses of the energy efficient motor.
- Improved rotor configuration and optimized rotor-to-stator air gap result in reduced stray load losses.
- An optimized cooling fan design provides ample motor cooling with a minimum of windage loss.
- Thinner and higher quality steel laminations in the rotor and stator core allow the energy efficient motor to operate with substantially lower magnetization losses.
- High quality bearings result in reduced friction losses.

Design of Premium Efficiency Motors needs
- special knowledge,
- experience and test facilities,
- equipped with precision instrumentation.



Efficiency and Rated power



Efficiency varies with rated power

Efficiency limit values

Rated Power (kW)	Rated Capacity (HP)	4-Pole Motor (Orthodox roller & Rotorvane)		6-Pole Motor (Trough fan)	
		IE1	IE3	IE1	IE3
0.75	1	72.1	82.5	70	78.9
1.1	1.5	75	84.1	72.9	81
1.5	2	77.2	85.3	75.2	82.5
2.2	3	79.7	86.7	77.7	84.3
3	4	81.5	87.7	79.7	85.6
4	5.5	83.1	88.6	81.4	86.8
5.5	7.5	84.7	89.6	83.1	88
7.5	10	86	90.4	84.7	89.1
11	15	87.6	91.4	86.4	90.3
15	20	88.7	92.1	87.7	91.2
18.5	25	89.3	92.6	88.6	91.7
22	30	89.9	93	89.2	92.2

Efficiency limit – varies with number of poles and rated power

Today, countries consuming more than 70% of the global electricity have set MEPS for motors either on IE2 or by 2015/17 on IE3 level.

This is a high level of international harmonization for a globally traded product, recognizing at the same time that MEPS levels can be different according to the market situation of countries.

Objectives

- **General objectives**

  To evaluate the feasibility of using high efficiency motors in tea processing machineries as an energy conservation measure

- **Specific Objectives**

– To determine and compare energy consumption by Present standard efficient Motor and high efficient motor in withering troughs, Orthodox Roller and Rotorvanes.

– To determine economic feasibility of the above energy saving measures and

– to explore the GHG mitigation potential and required financial support

Methodology

Selected machinery :

Location	Machine	Size	Motor capacity
Up-Country	Trough	58ft x 6ft	4 kW
Up-Country	Trough	42ft x 6ft	3 kW
Low-Country	Trough	70ft x 6ft	4 kW
Low-Country	Orthodox Roller	47 inch	15 kW
Up-Country	Rotorvane	15 inch	15 kW
Up-Country	Rotorvane	8 inch	11 kW

Controlled factors

Withering

- Leaf standard - 50 $\pm$ 2%
- Relative humidity - hygrometric difference 6 – 7 ^{0}F
- Degree of wither – 43% MT/WL
- Green leaf spreading rate - 2.5 kg / ft^2
- Trough conditions - no air leakages and no damages or holes in trough bed. Fan and motor conditions.
- Airflow maintained

Rolling in Orthodox Roller

- Leaf standard - 50 ± 2%
- Degree of wither – 43% MT/WL
- Machine conditions - properly lubricated, alignment checked and V-belts tighten
- Pressure – no pressure
- Leaf charged – 250 kg

Rolling in Rotorvanes

- Leaf standard - 50 ± 2%
- Degree of wither – 43% MT/WL
- Machine conditions - properly lubricated, alignment checked and V-belts tighten
- Pressure – endplate adjustment as required
- Leaf loading rate – 15 inch rotorvane – 30 kg/ min

  8 inch rotorvane – 16 kg/ min

Procedure – Withering

Checking Trough condition

↓

Arranging necessary instruments

↓

Checking GL standard

↓

Loading GL @ 2.5 kg/ft^2.

↓

Determining moisture content of GL

↓

Starting fan, controlling hygrometric difference and collecting data

↓

Turning the leaf.

↓

Turning off fan after achieving 43% MT/WL in WL

Procedure – Orthodox Roller

Checking condition of Roller

↓

Checking GL standard

↓

Arranging necessary instruments

↓

Determining Degree of wither in leaf

↓

Rolling 250kg of WL for 20 minutes

Procedure – Rotorvane

Checking condition of Rotorvanes

↓

Checking GL standard

↓

Arranging necessary instruments

↓

Adjusting End-plate

↓

Determining Degree of wither in leaf

↓

Rolling specified quantity of leaf in Rotorvane maintaining feeding rate

Data collection

- Energy consumption (kWh) – potable power analyzer

- Green leaf standard (%) – visual observation, Top loading balance

- Moisture content in green leaf (%) - oven and top loading balance
- Moisture content in withered leaf (%) – microwave oven and top loading balance
- Static pressure in Plenum chamber of withering trough (kPa)_- Pitot tube with micro manometer

- Temperature and relative humidity of withering air - Temperature / relative humidity logger

- Airflow (cfm) – Anemometer

- Feeding rate of leaf (kg/ min) – balance

Results and Discussion

Specific energy consumption – 58’ withering trough

Treatment	Specific Energy Consumption (Wh/ kg moisture removed)	Specific Energy Consumption (Wh/ kg MT)
Present Induction Motor	119.76	208.5
HEM	118.84	206.8
Savings	0.92	1.7

Saving is very marginal

Specific energy consumption – 42’ withering trough

Treatment	Specific Energy Consumption (Wh/ kg moisture removed)	Specific Energy Consumption (Wh/ kg MT)
Present Induction Motor	136.0	213.6
HEM	141.7	221.8
Savings	(-5.7)	(-8.2)

HEM consumed comparatively higher energy

Specific energy consumption – 70' withering trough

Treatment	Specific Energy Consumption (Wh/ kg moisture removed)	Specific Energy Consumption (Wh/ kg MT)
Present Induction Motor	90.6	157.2
HEM	97.7	169.5
Savings	(-7.1)	(-12.3)

HEM consumed comparatively higher energy

Uncontrollable factors

- HEM speed is high by 5- 10 rpm (less slip) –
  energy consumption by fans is proportional to the cube of rotational speed ⇒ higher energy consumption
- Fan design and performance curve
  - number of fan blades
  - fan blade size
  - fan hub size
  - Fan blade angle
  - Tip clearance
- Energy losses in transformation duct

Specific energy consumption – Orthodox Roller

Treatment	Specific Energy Consumption (Wh/ kg leaf charged)	Specific Energy Consumption (Wh/ kg MT)
Present Induction Motor	9.9	22.1
HEM	10.2	22.7
Savings	(-0.3)	(-0.6)

HEM consumed comparatively higher energy

Specific energy consumption – Rotorvanes

Machine	Equipment	Specific Energy Consumption (Wh/ kg leaf fed)	Specific Energy Consumption (Wh/ kg MT)
15 inch Rotorvane	Present motor	14.7	32.9
	HEM	14.1	31.6
	Savings	0.6*	1.3
8 inch Rotorvane	Present motor	4.1	13.2
	HEM	3.1	11.9
	Savings	0.6*	1.3

•Significant

Saving is achieved - not substantial

Feasibility of introducing HEM to Rotorvanes

Machine	15 inch Rotorvane	8 inch Rotorvane
Motor Capacity (kW)	15	11
Std motor price (Rs.)	134,000	117,000
HEM price (Rs.)	185,000 - 270,000	165,000 - 230,000

Very high prices – replacing the present motor with HEM is not feasible.
In typical industrial applications, energy-efficient motors are cost-effective when they operate more than 4,000 hours a year, given a two-year simple payback criterion.

Machinery - New installation with HEM instead of standard motor!

Machine	15 inch Rotorvane	8 inch Rotorvane
HEM Motor Capacity (kW)	15	11
Additional cost for installing HEM instead of Standard motor (Rs.)	51,000 - 136,000	48,000 - 113,000

Savings – 1.3 Wh/ kg MT

Assuming,

Green leaf moisture content – 77 %

Made tea nett outturn – 21.5%MT/GL

Working days per month – 27

Average electricity Cost – Rs.14.00/ kg MT

GL intake (kg)	15 inch Rotorvane		8 inch Rotorvane	
	Operating time (hrs)	Simple Payback (yrs)	Operating time (hrs)	Simple Payback (yrs)
4,000	346	10.1 – 26.8	648	9.5 – 22.3
6,000	518	6.7 – 17.9	972	6.3 – 14.9
8,000	691	5.0 – 13.4	1,296	4.7 – 11.1
10,000	864	4.0 – 10.7	1,620	3.8 – 8.9
12,000	1,037	3.4 – 8.9		
14,000	1,210	2.9 – 7.7		
16,000	1,382	2.5 – 6.7		
18,000	1,555	2.2 – 6.0		
20,000	1,728	2.0 – 5.4		

HEM as new installation become feasible in 15 inch Rotorvane

- Green leaf intake above 16,000 kg/ Day
- Low HEM price

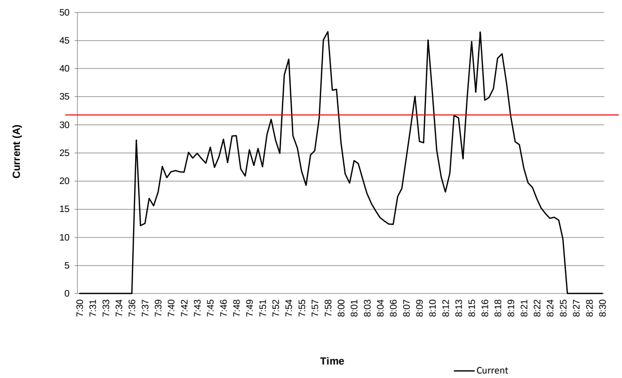
"CO_2" mitigation potential

GL (kg/ Day)	Energy saving (kWh/yr)	CO_2 mitigation / 15 inch Rotorvane (kg /yr)	CO_2 mitigation / 200 Rotorvanes (kg /yr)
10,000	906	652.0	130404
12,000	1,087	782.4	156484
14,000	1,268	912.8	182564
16,000	1,449	1,043.2	208646
18,000	1,630	1,173.6	234726
20,000	1,811	1,304.0	260808

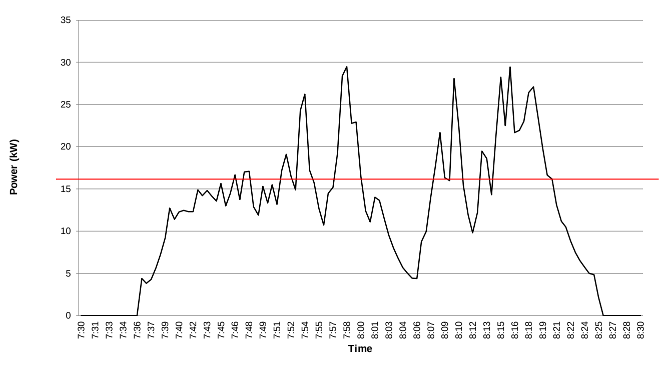
When GL intake is 16,000 kg/ Day,
"CO_2" mitigation > 1,000 kg/yr/ 15 inch Rotorvane

Installation of about 200 Rotorvanes over the years – more potential
Financial assistance could be explored

Energy saving potential with present standard efficient motor in 15 inch Rotorvane



Feeding rate of leaf into 15 inch Rotorvane is not controlled properly – current exceeded rated value



Power exceeded the rated value – 13 minutes out of 49 minutes

- energy loss
- wear & tear and breakage of machinery parts
- machinery breakdown due to motor failure

  (burnt, bearing failure)

Energy saving potential in 8 inch Rotorvane

Rolled leaf quantity (kg)	Rolling time	Output (kg/hr)	Specific energy (Wh/kg leaf fed)
20.3	25min & 30s	48	98.0
150.1	28min	322	14.4
78.5	10min & 30s	449	13.1
174.3	21min & 15s	492	10.1

Feeding rate & energy consumption were monitored

- under feeding led to lower specific energy consumption

(weighted average - 16.4 Wh/kg leaf fed)

Specific energy consumption at optimum feeding rate – 5.0 – 8.0 Wh/kg

Conclusions

- Energy saving cannot be achieved in withering troughs and Orthodox rollers by using high efficient motors.
- Energy saving achieved in 15 inch Rotorvane and 8 inch Rotorvane is not substantial.
- Replacing the present motor with HEM is not feasible in Rotorvanes due to very high cost.
- HEM could be considered for new installations of 15 inch Rotorvanes. This is possible when green leaf intake is above 16,000 kg/day and HEM could be obtained at lower cost.
- This measure could lead to “CO_2” mitigation potential. It could be more than 1 tonne/ yr/ Rotorvane.
- Energy saving could be achieved by proper control of feeding rate of leaf into Rotorvanes.

Future work

- Further study on use of high efficient motor in tea machinery and confirm energy saving potential.
- Identifying energy saving potential by proper operational practices and make recommendations.
- Estimate "CO_2" mitigation and explore possibilities for financial assistance and marketing tool for tea, "**Low "C" foot print product"**

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