ELECTRIC MOTOR REWINDING IN INDIA
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1 Executive Summary

India, world’s third largest consumer of electricity behind China and USA, consumed ~1.16 Mn GWh in FY19. The country’s electricity sector is dominated by fossil fuels, especially coal, leading to ~ 750 Mn T of Green House Gases (GHG) emissions. Being part of the Paris Agreement, India has pledged to reduce carbon emissions by 33-35% by 2030 as compared to 2005 levels. Bureau of Energy Efficiency (BEE) through its National Mission for Enhanced Energy Efficiency (NMEEE) is actively focusing on implementing innovative business models for energy efficiency thereby reducing carbon emissions.

Electric motors are extensively used in wide range of applications and hence important from energy efficiency perspective. Mechanical and electrical factors, working conditions, etc. damage electric motor windings. Frequent rewinding of electric motors using improper rewinding practices degrades the motor efficiency and therefore higher electricity consumption and each unit of extra power consumed leads to emission of 0.9kg of GHG emissions. This research paper deliberates on the practices followed for rewinding of electric motors in industrial LT motors, grid-connected agriculture pump motors and housing fans motors in India and potential energy savings by adopting best motor rewinding practices.

1.1 Industrial Application

About 3.27 Million units of industrial LT motors were produced in FY19, while the installed base of motors in FY19 was 39 Mn units. Average life of motor varies between 13 to 22 years depending on the end user industry. The average life of rewinding of >280 kW motors is better than lower capacity motors. Mechanical failure (vibration transfer, frequent start/ stop, overloading) accounts for ~60% of the winding failure while 1/4th of the total failure is due to electrical reasons (single phasing, voltage fluctuations). ~12 Mn LT induction motors were rewinded in FY19 constituting 30% of the LT motors installed base. Unauthorized rewinders accounted for 70% share of the LT industrial motors rewinding market, as accessibility, time for delivery of rewinded motors and trust are key factors for end-users. Only 20% of the motors are rewinded by authorized rewinders, as they are preferred only when the motors are within the warranty period.

1.2 Agriculture Applications

~ 1.98 Mn units of agriculture pump motors were sold in FY19 and ~20 Mn grid-connected agriculture-pumps are installed in India in FY19. The average life of the agriculture pump motors varies based on its working condition, quality of winding/rewinding, operational hours, ground water level, and the maintenance practice, etc. For >11kW motors, the average life of is 3.6 while that of <2.2kW motors is 1.7. About 50% of agriculture-pump’s motor winding failure can be attributed to external influence (low water level, dust & debris). ~6.8 Mn agriculture pumps were rewinded in FY19 which accounts to ~34% of the installed base. Unauthorized rewinders have 80% market share of the total rewinding market, as they are situated closer to end-users, who prefer fast and cost-effective service.
1.3 Housing Fans Applications

About 162 Million units of housing fan motors were sold in FY19 (Figure 31) of which ceiling fans have a share of 90%. The installed base of housing fans in FY19 was 1.21 Bn units, which included ~84% regular fans and ~7% exhaust fans. A regular branded ceiling fan have a life of 14 years while exhaust fans have life of 15 years. For branded ceiling fans the average life after rewinding is 3 years while for local fans (with aluminium windings) is just 1.2 years. About 80% of the failure of ceiling fan is attributed to the mechanical reasons (bearing failures), whereas, oil and dust is the sole reason for exhaust fan failure. ~170 Mn of housing fans were rewinded in FY19 which is ~14% of the installed base. The users generally call the local electrician who takes the fan motor to the local rewinder (unauthorized rewinder). Users go to fan dealers or the fan collection centres, if the fan is within warranty, who in turn replaces/repairs the fan.

1.4 Savings by adopting best rewinding practices

By following best motor rewinding practices, India could substantially save on energy cost and reduce carbon emissions.

<table>
<thead>
<tr>
<th>Details</th>
<th>Unit</th>
<th>Industrial Applications</th>
<th>Agriculture Pumps</th>
<th>Housing Fans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Energy Saving</td>
<td>Bn Units</td>
<td>23.81</td>
<td>7.24</td>
<td>2.12</td>
</tr>
<tr>
<td>Estimated Energy Saving</td>
<td>INR Cr</td>
<td>15,478</td>
<td>3,258</td>
<td>1,378</td>
</tr>
<tr>
<td>Reduced Carbon Emissions</td>
<td>Mn Tons</td>
<td>21.43</td>
<td>6.52</td>
<td>1.91</td>
</tr>
</tbody>
</table>

1.5 Rewinding Scenario in India

*Difference between best practice, authorized rewinder and unauthorized rewinder*

<table>
<thead>
<tr>
<th>Steps</th>
<th>Best practices</th>
<th>Authorized rewinding</th>
<th>Unauthorized rewinding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Inspection</td>
<td>• Recording basic information of the motor</td>
<td>• Recording basic information of the motor</td>
<td>• Basic information of the motor is recorded</td>
</tr>
<tr>
<td></td>
<td>• Refer to the motor related guidelines provided by the OEM</td>
<td>• Guidelines are provided by OEMs but they are often ignored</td>
<td>• Do not have any guidelines to follow for rewinding</td>
</tr>
<tr>
<td>Steps</td>
<td>Best practices</td>
<td>Authorized rewinding</td>
<td>Unauthorized rewinding</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dismantling the motor</td>
<td>• Disassemble the motor on a workbench</td>
<td>• Most of them use work bench for smaller capacity motors while dismantling</td>
<td>• Depending on the size of the motor, workbench may not used</td>
</tr>
<tr>
<td>Inspecting the damaged winding condition</td>
<td>• Check the condition of the winding and note down the connections</td>
<td>• All the winding condition details, and the winding diagram are noted</td>
<td>• All the winding condition details, and the winding diagram are noted</td>
</tr>
<tr>
<td>Removing the old winding and cleaning the slots</td>
<td>• Remove the damaged winding using shear clippers after melting the varnish in heating oven, cleaning agent and sandpaper.</td>
<td>• Heating ovens, cleaning agents &amp; sandpaper are used to clean the slots</td>
<td>• Flame is used to burn varnish and chisels are used to scrap old winding</td>
</tr>
<tr>
<td>Winding new coils</td>
<td>• Wind the coils using automated winding machine</td>
<td>• Manual process to wind the coils</td>
<td>• Manual process to wind the coils</td>
</tr>
<tr>
<td>Inserting the coil into the slots</td>
<td>• The new insulation paper and coils are inserted manually into the slots</td>
<td>• Insulation paper and coils are inserted manually into the slots</td>
<td>• Insulation paper and coils are inserted manually into the slots</td>
</tr>
<tr>
<td>Perform winding tests</td>
<td>• Insulation resistance test</td>
<td>• Only few of the unauthorized rewinders perform the winding test after rewinding</td>
<td>• Insulation resistance test</td>
</tr>
<tr>
<td>Applying varnish on the coils</td>
<td>• Coat the coils with varnish after connecting all the</td>
<td>• Varnish is applied manually on the coils</td>
<td>• Varnish is applied manually on the coils</td>
</tr>
<tr>
<td>Steps</td>
<td>Best practices</td>
<td>Authorized rewinding</td>
<td>Unauthorized rewinding</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------</td>
<td>----------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td></td>
<td>wires and then assemble the motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor performance tests</td>
<td>Tests to be performed on the motor • No load test • Locked rotor test • Reduced voltage running up test (up to 37kW)</td>
<td>• Only no-load tests are performed on the rewinded motors that of upto 7.5 kW capacity</td>
<td>• Most of them only perform running test on the rewinded motors that to for small capacity motors</td>
</tr>
</tbody>
</table>

1.6 **Key Recommendations**

**Recommendation – Industrial applications**

- Create awareness regarding preventive motor maintenance practice in the industrial end-users specifically the SMEs to make them understand the importance of simple preventive maintenance and its effect on the life.
- Create awareness about the best rewinding practice by conducting an awareness program in the end-user industries to demonstrate the energy loss, efficiency loss and reduction in life after rewinding using improper practices.
- The end-users should inculcate the practice of periodically checking and documenting motor related parameters like motor load, current drawn, coil resistance, insulation conditions, etc.
- SME industries do not conduct energy audits and continue with inefficient machinery and rewinding practices. Government could conduct a cluster-based audit and identify the inefficient units. These units can be provided high efficiency IE3 motors at discounted price.

**Recommendations – Agriculture Applications**

- The industry stakeholders (government, OEMs, and associations) should create awareness amongst farmers that proper rewinding increases pump throughput and improves the life of pump.
- OEMs (with government’s support) should develop their dealers/distributors to provide operation and maintenance (O&M) services, thereby ensuring higher efficiency.
- Government could subsidize farmers using BEE approved pumps as these motors have longer life and much higher efficiency. BEE new norms, if made mandatory, will result in more efficient pumps used by the industry.
Recommendations for implementing best practice among authorized rewinders

- Currently, most rewinders are not providing test reports. The government should mandate that all authorized rewinders to provide test certificates after rewinding.
- The rewinders must be made aware of the benefits of using automatic coil winding machine to improve the winding packaging which reduces the efficiency loss in the motor after rewinding.
- OEMs should conduct mandatory training sessions at least once a year for all authorized rewinders, so that they are well versed with the best rewinding practice.
- The motor manufacturing companies / associations could develop an online data bank which can be accessed by all the rewinders. The data bank may consist of motor model specific information like winding diagrams, copper gauge, coil length, etc.

Recommendations for implementing best practice among unauthorized rewinders

- Currently, no industry stakeholder is responsible of maintaining and regulating the unauthorized rewinders in the market. Government bodies like BEE can certify the rewinders based on key parameters.
- Under Skill India program, the government can develop and support training sessions for such untrained rewinders. This training can be conducted on a regional/district level in the ITI or other skill centers located in the vicinity.
- Government should promote setting-up of testing facilities in the industrial clusters, to confirm the motor efficiency.

Recommendations for ceiling fan replacement instead for rewinding

- OEMs should promote the shift towards BEE 5-star rated fans by providing exchange offers over regular fan so that the end-user can replace them with efficient fans instead of rewinding. There are substantial savings if end-user replaces their regular fan with BEE 5 Star rated fan.

Recommendations for LT Induction motor replacement instead for rewinding

- There are substantial savings if end-user replaces their old LT Induction motor with IE3 motor. OEMs should promote the shift towards IE3 motors by providing the cost savings achieved if old motors are replaced instead of rewinding.
2 Introduction

India’s electricity consumption in FY19 was ~1.16 Mn GWh\(^1\), growing annually at 6.6% in the last 10 years. More than 70%\(^2\) of this electricity is produced using fossil fuels, leading to around 750\(^2\) Mn T of Green House Gases (GHG) emissions.

In the multilateral Paris Agreement (2016), India pledged to reduce carbon emissions by 33-35%\(^3\) by 2030, compared to 2005 levels.

One of the key programs of Bureau of Energy Efficiency (BEE) is National Mission for Enhanced Energy Efficiency (NMEEE)\(^4\) which has been established under the National Action Plan on Climate Change (NAPCC) to strengthen the market for energy efficiency through implementation of innovative business models in the energy efficiency sector.

Frequent rewinding of electric motors using improper rewinding practices degrades the motor efficiency and therefore higher electricity consumption and each unit of extra power consumed leads to emission of 0.9kg of GHG emissions\(^5\). This research paper discusses the practices followed for rewinding of electric motors in India and potential energy savings by adopting best motor rewinding practices.

Electric motors are the most used prime movers in the 21\(^{st}\) century owing to its wide application and lower maintenance requirement as compared to that of petrol and diesel-based engines.

The paper covers three main motor applications namely industrial LT motors, grid-connected agriculture pumps and housing fans. The report intends to:

- Investigate the current rewinding practices;
- Identify best rewinding practices;
- Estimate the savings in electricity and carbon emission by using the best practices; and
- Recommend a detailed action plan for the industry participants, government and the users.

Industrial sector consumed around ~42% or electricity and the consumption is growing at a CAGR of 8.4%\(^1\) (FY12-19), primarily driven by 4.3% growth in manufacturing activities during FY 12-19. India’s vision of becoming a US$ 5 trillion economy is expected to drive significant growth in the manufacturing sector. Through ‘Make in India’ initiative, domestic capability development will also witness a strong boost.

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1. Energy Statistics 2020 - MOSPI
4. BEE Website
5. Rensmart and UK Parliamentary Office of Science and technology [https://www.rensmart.com/Calculators/KWH-to-CO2](https://www.rensmart.com/Calculators/KWH-to-CO2)
**LT Induction motors** are commonly used for various industrial applications. Most motors used in the industrial sector are of <7.5 kW capacity, accounting to 86% of the units installed but it accounts for 31% of electricity consumed by the overall LT motors installed base.

The agriculture sector is the primary source of livelihood for about 58% of India’s population. Due to better electric connectivity in the rural areas, farmers are shifting from diesel-driven pumps towards electric pumps due to their lower operating cost. In the agriculture sector, grid-connected pumps installation stands at 19.7 Mn units across India with an energy rating of 100 GW. Among the wide range of motor capacities available, 3.7 kW & 5.5 kW motors have a combined share of over >50% in the installed base both in terms of number of units installed and energy ratings.

**Housing fan** has witnessed an annual growth rate of 11% over the past 10 years, reaching an installed base of 1.2 Bn units of ceiling fans and around 82.5 Mn units of exhaust fans. Unlike European countries, India is a tropical country, making housing fans a necessity in all residential buildings. The growth in the market is fuelled by increasing electrification, especially in rural India and growth in the construction sector.

In case of winding damage or burn-out, rewinding of motors is a common practice across the above-mentioned applications in India. This increases the life of the motor by replacing its damaged winding with a new set of winding. The winding damages are due to electrical and mechanical reasons like working environment, overload, voltage fluctuations, etc.

~30-40% of the installed industrial and agricultural motors and ~15% of the installed housing fans were rewinded almost every year.

Even though rewinding a motor is an economical solution than purchasing a new motor, it may have a significant impact on the efficiency of the motor leading to higher cost of operation.

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6 - IEEMA Data
7 - IBEF Report - Agriculture in India: Information About Indian Agriculture & Its Importance
8 - Market Research of Agriculture Pump-sets Industry of India - Shakti Sustainable Energy Foundation and AGR estimations with CAGR of 6.3%
9 - News articles and primary research with industry experts
10 - AGR Analysis
3  Industrial Application

3.1  Production of LT Induction motor

LT Induction motors used in the industrial applications has seen a steady growth in demand at ~5% CAGR (FY10-FY19). This is due to increasing manufacturing activities, which has annually grown at a rate of 4.3% (FY12-FY19). About 3.27 Mn units of industrial LT motors were sold in FY19 (Figure 1), of which ≤7.5Kw motors have 85% production share by the number of units and 34% share by wattage.

Figure 1: LT Motor Production (Mn units)

Source: Production data form FY2010-19 as covered by IEEMA and estimates for IEEMA non-members

3.2  Installed base of Industrial Motors in India

Currently, ~39 Mn LT motors (Figure 3) are installed in India with a total capacity of 232 GW (Figure 4). In line with the LT motor production units, the installed base is also dominated by smaller size motors (≤ 7.5KW).
Pumps and blowers are the key applications of motors and accounts for ~60% of the total installed base.

In the current industrial context led by automation, motors are widely used for pumping based applications such as fluid transfer, hydraulic systems, and cooling. Compressors are used across...
all type of industries which are equipped with small capacity motors for various pneumatic based applications. 

Machineries such as crushers, lathe, printing machines, etc. are installed with a wide variety of motor capacities which are used as a prime mover to perform various tasks.

3.3 Industrial End-user segments

The end-users of Industrial LT motor are classified into three categories as the life of rewinding and the preferences for rewinding the motor varies accordingly. The classification in Customer Segment A, B & C is based on the inherent characteristics such as the size of the industry, working condition, maintenance practices, etc.

Customer Segment A and B tend to have better preventive maintenance practice vis-à-vis Customer Segment C. This leads to lower failure rate and higher life of rewinding.

Customer Segment C consists of the SME industry that operates in an unregulated working environment. Poor maintenance practice and inadequately designed plant lead to a higher motor failure rate.

Table 1: Customer Segments

<table>
<thead>
<tr>
<th>Industry Size</th>
<th>Customer Segment A</th>
<th>Customer Segment B</th>
<th>Customer Segment C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Scale Industries</td>
<td>Well configured plant layout</td>
<td>80% of the overall industrial electricity consumption</td>
<td>Inadequately designed</td>
</tr>
<tr>
<td>Mid-size industries</td>
<td>Controlled</td>
<td>High temperature/dust</td>
<td>Unregulated</td>
</tr>
<tr>
<td>SMEs</td>
<td>Regular</td>
<td>Negligible</td>
<td>1 shift i.e. 10 hrs. a day</td>
</tr>
<tr>
<td>3 shifts i.e. 24 hrs. a day</td>
<td>2 shifts i.e. 16 hrs. a day</td>
<td>Metal Forging, Textile Processing Units, etc.</td>
<td>Weavers, Sugar, Metal Workshops, etc.</td>
</tr>
<tr>
<td>Paper, Chemical, Integrated Synthetic Textile, etc.</td>
<td>Metal Forging, Textile Processing Units, etc.</td>
<td>Weavers, Sugar, Metal Workshops, etc.</td>
<td>1 shift i.e. 10 hrs. a day</td>
</tr>
</tbody>
</table>

Source: AGR Analysis

3.4 Reasons for motor winding failure

Motor winding failure can be attributed to mechanical or electrical reasons and the working environment within the industrial facility. Mechanical failure accounts for ~60% of the winding failure. 1/4th of the total failure is due to electrical reasons.
Mechanical Failure: Winding burn out originating from failure of physical origin is known as mechanical failure. Mechanical failure can be sub-segmented into vibration transfer, frequent start/stop and overloading of the motor.

The main impact of vibration transfers and overload is reflected on the bearing and shaft of the motor resulting in their failure after their tolerable stress limit is passed which can then damage the winding due to uneven load/stress distribution.

Frequent start/stop of the motor results in winding burn out as the flux generated during the starting sequence of the motor requires greater force to be generated to start the motor from its idle position.

Electrical Failure: Breakdown of motor happens due to unstable electrical connectivity or power supply resulting in failure of motor winding.

Single phasing is one of the most common failures in the SME industries that may have a poorly planned electrical layout. In the Single phasing, a phase of electrical connection gets disconnected from the 3-phase power supply creating flux from only two phases which burns out the motor winding.

Voltage fluctuations are witnessed in an industrial area situated in remote locations, due to poor electricity supply, resulting in winding burnout.

Working Conditions: Winding failure due to accumulation of dust/particles, heat from the work environment or long working hours are classified as failure due to working condition. High dust & high temperature and long working hours cause conditional failures in motors.

Dust/particles generated due to the industrial operation itself like in cement and ceramic industries or high working temperatures like in forging or extrusion industries impart stress in winding and mechanical parts of the motor. Such working conditions usually lead to early failure of the motor windings. Overheating of motor due to long working hours can also lead to eventual failure in the motor windings.

The severity of these causes is highly dependent on the customer segment the end-user belongs to and the type of applications the motor is exposed to.

Source: AGR Estimates
3.5 Average life of motor

The average life of LT Induction motor is the duration calculated from the date of installation till the date of discard. The motor goes through multiple rewinding within this time period. Motors are eventually discarded for the following reasons:

- The stator of the motor is damaged, and it cannot be repaired any further; or
- The cost-benefit analysis suggests that the cost incurred in operating the rewunded motor is higher than the cost of purchasing a new motor.

**Figure 7: Average life of LT Induction Motors (Years)**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Life (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPTO 7.5 KW</td>
<td>13</td>
</tr>
<tr>
<td>9.3 TO 37 KW</td>
<td>16</td>
</tr>
<tr>
<td>45 TO 280 KW</td>
<td>19</td>
</tr>
<tr>
<td>&gt;280 KW</td>
<td>22</td>
</tr>
</tbody>
</table>

*Source: AGR Estimates*

Though the life of motors varies based on its working condition, type of application, operational hours, and the maintenance practice, motors of higher kW ratings (Figure 7) generally have a longer life. This is attributed to higher endurance and robust mechanical design.

Motors of >280kW capacity motors have the longest average life of ~22 years due to its strong built. These motors are generally used by Customer Segment A&B who undertake regular preventive maintenance which also leads to enhance life of motor.

On the other hand, motors of ≤7.5kW capacity have the lowest life of 13 years. These motors are dominant in Customer Segment C (SME industries), where preventive maintenance is not practised. In many cases, these motors are part of large machines that are operated for a longer duration.

3.6 Average life of rewinding

The average life of rewinding is estimated as life after its first rewinding. The average life of rewinding of a motor (
**Figure 8** for different customer segments (A - Large, B - Medium, C - SMEs) highlight the fact that the life of motor rewinding is dependent on various factors such as rewinding quality and regular maintenance.

**Figure 8: Average life of rewinding (Years)**

![Graph showing average life of rewinding for different segments](image)

### Estimation of number of motors rewinded

AGR estimates that ~12 Mn LT induction motors were rewinded in FY19 constituting 30% of the LT motors installed base. This also accounts for ~53GW i.e. 23% of the LT motors installed base by power ratings. Motors of \(\leq 7.5\) KW has the highest share in the rewinding market both by units and by the power ratings.

**Figure 9: Number of motors rewinded (Units) – Source: AGR Estimates**

![Pie chart showing number of motors rewinded](image)
AGR estimates that only 7% of the motors rewinded in FY19 were from Customer Segment-A (Figure 11). This is due to the usage of higher capacity motors that have longer life of winding and comprehensive preventive maintenance practices.

On the other hand, SMEs accounts for over half of the 12 Mn rewinded motors.

Source: AGR Estimates
3.8 Rewinding preference of the end-users

For industrial applications, the end-users have three options for rewinding their motors.

*Figure 13: Rewinding preference for the Industrial LT motors*

- **Authorized Service Centers (ASCs)**
  Authorized Service Centers are appointed by the motor OEMs as their representative for providing maintenance services. End-users prefer ASCs when the motors are within warranty and when ASCs are located in the plant’s vicinity.

- **Unauthorized rewinders**
  Most of the industrial area have unauthorized rewinders situated within their vicinity. Even though repairs done by these rewinders are not authorized by the motor OEMs, they continue to get business due to the trust that they have built with the end-users.

- **In-house rewinding**
  In-house rewinding is prominent with the industries where rewinding service is not available in proximity or where many small capacity motors (≤ 7.5KW) are installed in the industrial facility. However, this is a fading trend, as the availability of local rewinders is increasing and industries don’t want to maintain an in-house inventory of motor spares.

3.9 Estimation of motors rewinded according to end user preference

Unauthorized rewinders have over 70% of the LT industrial motors rewinding market. Only 20% (Figure 14, Source: AGR Estimates
Figure 15) of the motors are rewinded by authorized rewinders, as they are preferred only when the motors are within the warranty period.

Figure 14: Number of motors rewinded in FY19 – Rewinders (Units)

![Figure 14](image1.png)

Source: AGR Estimates

Figure 15: Number of motors rewinded FY 19 – Rewinders (GW)

![Figure 15](image2.png)

Source: AGR Estimates

3.10 Savings by adopting best rewinding practices

The potential amount of energy that could have been saved in FY19\(^{11}\) by adopting best rewinding practices is approximately 24 BU, which is equivalent to around INR 15,500 Cr\(^{12}\). The best rewinding practice also results in reduction of 21.5 Mn Tons in GHG emissions\(^{13}\).

\(^{11}\) Discussion with industry experts, end users, rewinders and OEMS

\(^{12}\) cost of per unit electricity = INR 6.5 Rs/kW as per ICF report on study to 'Evaluate & Demonstrate the Economic Loss Due to Rewinding of LT Motors

\(^{13}\) 1 unit of electricity consumed is 0.9 kg/kWh. [https://www.rensmart.com/Calculators/KWH-to-CO2](https://www.rensmart.com/Calculators/KWH-to-CO2)
4 Agriculture Application

4.1 Agriculture pump sales

Agriculture pumps have seen a steady increase in demand at an annual growth rate of 5.1% (FY10-FY19). The growth is fuelled by better electric connectivity in the agricultural areas and due to subsidized cost of power. About 1.98 Million units of Agriculture pump motors were sold in FY19 (Figure 17), of which ≤3.7Kw motors have a 55% sales share in terms of number of units sold and 32% share by wattage terms.

Figure 17: Agriculture Pump Motor Sales (Mn units)

Source: Market Research of Agriculture Pump-sets Industry of India & AGR Estimates
4.2 Installed base of Agriculture pump in India

Currently, ~20 Mn (Figure 19) grid-connected agriculture-pumps are installed in India with a total capacity of about 100 GW (Figure 20). Motors of 3.7KW and 5.5 KW are the most preferred model and account for ~60% of the installed base.
The industry is also characterized by a large number of unorganized OEMs that have a strong regional presence.

4.3 Reasons for motor failure

Agriculture-pump’s motor winding failure can be attributed to external influence or electrical failure or mechanical failure. External influence accounts for over 50% of the winding failure.
**Figure 22: Reasons for failure**

<table>
<thead>
<tr>
<th>External Influence</th>
<th>40%</th>
<th>12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Failure</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>Mechanical Failure</td>
<td>13%</td>
<td>10%</td>
</tr>
</tbody>
</table>

- **External Influence**: Winding failure due to accumulation of dust/particles or drop in underground water level below the working limit of the motor is classified as a failure due to external influence.
  - For example, dust/debris, small animals (rats, rabbits, frogs, etc.) and dirt are present on the farm all the time. This can result in damage of winding and mechanical parts of the motor.
  - Dry running of motor due to a drop in underground water level can also lead to failure in the motor windings.

- **Electrical Failure**: Breakdown of motor due to faulty electrical connectivity or unstable power supply results in failure of motor winding.
  - Single phasing is one of the most common failures in agriculture areas. A phase of electrical connection gets disconnected from the 3-phase power supply creating flux from only two phases to flow into the motor, which burns out the winding.
  - Voltage fluctuations are seen in rural areas, situated in remote locations which face variations due to poor electricity supply resulting in winding burnout.

- **Mechanical Failure**: Winding burn out originating from failure of physical origin is known as mechanical failure. Vibration transfer and impeller failure are the key reasons for mechanical failure.
  - Vibration transfer impacts the bearing and shaft of the motor resulting in their failure after their tolerable stress limit is passed. This uneven load/stress distribution on the bearing or shaft can damage the winding.
  - Impeller damage as a result of foreign particles in the water wears down the impellers causing unbalanced stresses on the motor shaft eventually leading to winding failure.

The severity of these causes is highly dependent on the location of the farmland.

*Source: AGR analysis*
4.4 Average life of motor

The average life of agriculture pump motor is the duration from its date of installation till the date of discard. The motor goes through multiple rewinding within this time. Agriculture-pump motors are discarded when the stator of the motor is damaged as such that it cannot be repaired any further.

Though, the life of the motors can vary based on its working condition, quality of winding/rewinding, operational hours, ground water level, and the maintenance practice, motors of higher kW ratings (Figure 23, Figure 7) generally have longer life. Also, the dominance of organized players increased with the increase in the pump capacity.

4.5 Average life of rewinding

The average life of rewinding is estimated as life after its first rewinding.

Motors of 7.5kW and ≥11KW capacity have the better life due to the build of the motor, and as these are usually submersible pumps which have an enclosed structure and operate underground.

Similarly, motors of ≤2.2kW capacity has the lowest life of 12 years is because they are Monoblock pumps working in open environment prone to damage from external influence.
4.6 Estimation of number of motors rewinded

AGR estimates that ~6.8 Mn agriculture pumps were rewinded in FY19 which is ~34% of the installed base. This also accounts for ~31GW i.e. 31% of the installed base by the power ratings. Motors of 3.7 KW has the highest share in the rewinding market both by units and KW (Figure 25, Source: AGR estimates)

Figure 26).

Figure 25: Number of motors rewinded (Units)

Source: AGR estimates

Figure 26: Capacity of motors rewinded (GW)

Source: AGR estimates
4.7 Preference of End-users for rewinding of motors

For agricultural applications, the end-users have two options for rewinding their motors.

*Figure 27 Rewinding preference for the agriculture pumps*

Source: AGR analysis

**Authorized Service Centres (ASCs)**

Authorized Service Centers are appointed by the pump OEMs as their representative for providing maintenance services. End-users prefer ASCs when the motors are within warranty and when ASCs are in the farm’s vicinity.

**Unauthorized rewinded**

Most of the farms area have unauthorized rewinders situated within their vicinity. Even though repairs done by these rewinders are not authorized by the motor OEMs, they continue to get business due to the trust that they have built with the end-users.

4.8 Rewinding preference of the end-users

Only 1/5th (Figure 28, Source: AGR estimates) of the motors are rewinded by authorized rewinders, as they are not easily accessible and are preferred only when the motors are within the warranty period.
Motors of all capacities are mainly rewinded by unauthorized rewinders having 80% market share of the total rewinding market, as they are situated closer to end-users, who prefer quickly and cost-effective service.

Figure 28: Number of motors rewinded in FY19 – Rewinders (Units)

Source: AGR estimates

Figure 29: Number of motors rewinded FY 19 – Rewinders (GW)

Source: AGR estimates

4.9 Savings by adopting best rewinding practices

The potential amount of energy that could have been saved in FY2019 by adopting best rewinding practices is approximately **7.24 BU**, which is equivalent to around **INR 3,258 Cr**\(^{14}\). The best practice also results in a reduction of **6.52 Mn Tons in GHG emissions**\(^{15}\).

Figure 30: Saving potential

\(^{14}\) Cost of per unit electricity in India is INR 4.5 Rs/kW. ICF report ‘Evaluate & Demonstrate the Economic Loss Due to Rewinding of LT Motors’

\(^{15}\) 1 unit of electricity consumed is 0.9 kg/kW. [https://www.rensmart.com/Calculators/KWH-to-CO2](https://www.rensmart.com/Calculators/KWH-to-CO2)
5 Housing Fan Application

5.1 Housing fan sales

Due to the rapid urbanization of settlements, housing fan motor used in residential applications have seen a rapid increase in demand at ~11% (FY10-FY19). About 162 Million units of housing fan motors were sold in FY19 (Figure 31) of which ceiling fans have a lion’s share of 90%.

*Figure 31: Housing Fan Sales (Mn units)*

![Housing Fan Sales Graph](image)

*Source: AGR estimates*

5.2 Installed base of housing fans in India

The installed base for housing fan motors (Figure 32) is segmented into various types. As BEE 5-star rated fan and super-efficient fan are new introduction in the housing fan market, its adoption has been limited to the urban area and new residential projects.

*Figure 32: Installed base of Housing Fan Motors in FY19 (GW)*

![Installed base of Housing Fan Motors](image)

*Note: The no of housing fan units sold consists of ceiling and exhaust fan*

*Source: AGR estimates*

About 70% of the ceiling fan market is organized. The winding material used for ceiling fans by organized manufacturers is copper, while the unorganized manufacturers mainly use aluminium as their winding material.
5.3 Ceiling Fan Manufacturers segments

The ceiling fan manufacturers are classified in three segments as the life of ceiling fan changes according to its make and the material used for winding the coil.

Table 2: Ceiling Fan Manufacturers Segment

<table>
<thead>
<tr>
<th>Type of players</th>
<th>CEILING FAN MANUFACTURER - A</th>
<th>CEILING FAN MANUFACTURER - B</th>
<th>CEILING FAN MANUFACTURER - C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winding material used</td>
<td>Organized</td>
<td>Unorganized</td>
<td>Unorganized</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>Copper</td>
<td>Aluminium</td>
</tr>
</tbody>
</table>

Source: AGR analysis

5.4 Reasons for motor failure

About 80% of the failure of ceiling fan is attributed to the mechanical reasons (Figure 34), whereas, oil and dust is the sole reason for exhaust fan failure (Figure 35)
**Figure 35: Exhaust Fans – Reasons for motor failure**

![Bar chart showing oil and dust (Exhaust Fans) as the main reason for motor failure with 90%]

Source: AGR estimates

**Mechanical Failure:** Bearing failure in the motor shaft is the main reason for mechanical failures in housing fan motors. Ceiling fans bearings are loaded with the entire weight of the fan. This results in winding failure, if the quality of the bearing used in the fan is not suited for long stretches of operation under load, leading to damaging the winding of the motor.

**Electrical Failure:** Breakdown of motor due to unstable electrical connectivity or power supply results in winding failure. Electrical failure is prominent in the rural/remote areas which faces variations due to poor electricity supply.

**External Influence (specifically for exhaust fans):** Winding failure due to accumulation of dust/particles and oil residue are classified as failure due to working condition. Dust particles generated due to the operation of exhaust fans used in kitchen or deposition of cooking oil residue while cooking can eventually jam the parts of exhaust fan with small tolerances. Such working conditions can lead to eventual failure in the exhaust motor windings.

5.5 **Average life of motor**

The average life of a housing fan motor is the duration from its installation date until it is discarded. Motors are discarded for the following reasons:

- The laminated layers of the stator being damaged due to burnout of winding, that it makes it impossible to perform rewinding on the motor
- Sometimes jamming of the parts due to oil/dust deposit in the exhaust fan is high enough to damage the part making it impossible to perform rewinding on the motor
Regular ceiling fan has a long life as they are not subjected to overloading and have good working conditions in the urban household. Ceiling fans manufactured by unorganized players with aluminum winding have a shorter life.

An Exhaust fan is installed mainly in the kitchen and is operated for only 1-3 hours per day. Hence, it has a longer life.

5.6 Average life of rewinding

The average life of rewinding is estimated as life after its first rewinding.

Winding failure in fans manufactured by unorganized sector due to poor quality of parts being used to manufacture and repair the fan which reduces the winding life significantly.

AGR analysis based on interviews with rewinders and end users
Exhaust fans have a greater life expectancy as they are not operated frequently and are enclosed to prevent damage to the parts due to oil and dust.

5.7 Estimation of number of motors rewinded

AGR estimates that ~170 Mn of housing fans were rewinded in FY19 which is ~14% of the installed base (Figure 38)

*Figure 38: Number of housing fans rewinded (Units)*

Source: AGR estimates

Approximately, half of the motors rewinded in FY19 (Figure 38) were of fans manufactured by the organized players, as they have 75% share in housing fan motor installed base.

5.8 Customers rewinding preference

*Figure 39: Fan rewinding preference*
For housing fan applications, the users generally call the electrician who takes the fan motor to the local rewinder (unauthorized rewinder). Users reach out to the fan dealers or the fan collection center, if the fan is within warranty, who in turn replaces the fan.

5.9 Savings by adopting best rewinding practices

The potential amount of energy that could have been saved in FY19 by adopting best rewinding practices is approximately 2.12 BU & 0.012 BU for ceiling and exhaust fans, respectively. This is equivalent to INR 1,378 Cr & 7.8 Cr for ceiling and exhaust fans, respectively\textsuperscript{18}.

The best practice also results in reduction of GHG emissions by 1.91 Mn Tons & 0.0108 Mn Tons\textsuperscript{19}.

\textit{Figure 40: Saving potential for ceiling fan market}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{saving_potential.png}
\end{figure}

\textsuperscript{18} cost of per unit electricity in India is INR 6.5 Rs/kW
\textsuperscript{19} 1 unit of electricity consumed is 0.9 kg/kW
6  Rewinding Scenario in India

6.1 LT Induction Motors – OEM criteria while appointing ASCs

Though OEMs have various criteria to select the authorized service center (ASC). Key requirements include working area, skilled staff, work experience of the rewinders, in-house testing & winding equipment and willingness to provide service in a specific geography.

*Figure 41 OEMs’ requirements to select the authorized service center (ASC)*

<table>
<thead>
<tr>
<th>Working Area</th>
<th>STAFF</th>
<th>TESTING EQUIPMENT</th>
<th>SERVICEABLE AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on area of the workshop and other related infrastructure, rewinder is</td>
<td>Minimum number of staff required. However,</td>
<td>Basic testing equipment to perform surge test,</td>
<td>Its mandatory to serve all customers</td>
</tr>
<tr>
<td>authorized for a specific frame size rewinding</td>
<td>the qualification of the staff is not a key</td>
<td>resistance test, high voltage/amperage test is a</td>
<td>of the OEM within a certain km range</td>
</tr>
<tr>
<td></td>
<td>requirement</td>
<td>necessity. Load testing equipment is not a mandatory</td>
<td></td>
</tr>
<tr>
<td>Working Area</td>
<td></td>
<td>requirement</td>
<td></td>
</tr>
<tr>
<td>Skilled Staff</td>
<td>Work Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The minimum number of staff required to ensure quick service to the customers</td>
<td>Rewinders with 10+ years of experience are</td>
<td></td>
<td></td>
</tr>
<tr>
<td>However, the qualification of the staff is not a key requirement.</td>
<td>preferred</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work Experience of Rewinder</td>
<td>WINDING &amp; OTHER EQUIPMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rewinders with 10+ years of experience are preferred.</td>
<td>• Equipment like oven, winding jig and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appointing experienced rewinders as the ASCs increases the trust of</td>
<td>other tools are obligatory depending on the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>customers on the OEM.</td>
<td>OEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-house Testing Equipment</td>
<td>• VPI equipment is only required in areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic testing equipment to perform surge test, resistance test, high</td>
<td>where IE3 motors are popular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>voltage/amperage test is a necessity. However, load testing equipment is not</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a mandatory requirement.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: AGR analysis*

**Working Area**
- Based on the area of the workshop and other related infrastructure, rewinder is authorized for a specific frame size rewinding.

**Skilled Staff**
- The minimum number of staff required to ensure quick service to the customers. However, the qualification of the staff is not a key requirement.

**Work Experience of Rewinder**
- Rewinders with 10+ years of experience are preferred. Appointing experienced rewinders as the ASCs increases the trust of customers on the OEM.

**In-house Testing Equipment**
- Basic testing equipment to perform surge test, resistance test, high voltage/amperage test is a necessity. However, load testing equipment is not a mandatory requirement.
In-house Winding & Other Equipment

- Equipment like oven, winding jig and other tools are compulsory depending on the OEM. The equipment is easily available with most of the genuine rewinders.
- Vacuum Pressure Impregnation (VPI) equipment is only required in areas where IE3 motors are popular.

Service Area

- It is mandatory to serve all customers of the OEM within a specific area, even if the motor is not repairable. The rewinder must attend the end-user complaint.

6.2 LT Induction Motors – Interaction between OEMs and ASCs

OEMs invest in training of the rewinders. OEMs conduct audits to measure the performance of the rewinders. OEMs also provide a rewinding guideline to the rewinders; however, the guideline does not include data related to the winding diagram, gauge, coil length, etc.

*Figure 42 Interaction between OEMs and ASCs*

**Source:** AGR analysis

**Training**

- Annual training is organized by most OEMs to keep the rewinders updated about the motor winding procedure.
- Training is generally mandatory when new models are launched in the market.

**Audits by OEMs**

- Most OEMs conduct annual audit, where information regarding the number of motors repairs, customer feedback and repair logbook are checked to evaluate service performance.
• Equipment calibrations are checked to ensure that the quality check of rewinded motor is being recorded correctly.

Components

• Custom components (specific to model and make) are provided by the OEM, whereas, generic spares are procured from the market.
• Copper winding wires are purchased by ASCs from the market.

Guidelines

• Guideline includes
  o Troubleshooting Tips – Regarding operational problems, causes and further steps to be taken.
  o Motor’s exploded view & component list so the rewinders can buy or order the parts when required.
  o Basics procedure/key points to be followed while servicing a motor such as procedure to remove oil seal without damaging them and other key steps.
• Guidelines don’t include motor specific information like winding diagrams, copper gauge, number of winding turns
  o Winding diagrams (Only disclosed to ASCs to repair motors in warranty)
  o Copper gauge/Coil length
  o Number of turns – The rewinders count the turns from the coil of the motor that has come for repair.
6.3 Process for repair following best practices – LT Induction Motor

*Figure 43: Best rewinding practice*

**Preliminary Inspection**
Recording basic information of the motor such as kW rating, model number, reason for damage, etc. Refer to the motor related guidelines provided by OEM.

**Dismantling the motor**
Disassemble the motor on a workbench and take note of the parts being removed and check their condition for any damage.

**Inspecting the damaged winding condition**
Check the condition of the winding to deduce the reason for failure and note down the connections.

**Removing the old winding and cleaning the slots**
Remove the damaged winding using shear clippers after melting the varnish in heating oven (few OEMs discourage heating oven), clean the slots using cleaning agent and sandpaper. Then insert new insulation paper into the slots.

**Winding new coils**
Wind the coils using automated winding machine to achieve better coil packaging and use correct gauge and quality of wire.

**Perform winding tests**
After inserting the coils, the winding must be evaluated for its resistance and insulation. Following test must be conducted to ensure motor reliability after repairs:
- Insulation resistance test
- Measurement of stator resistance
- High voltage test

**Inserting the coil into the slots**
New coils are inserted into the slots, then covered and isolated with insulation paper. Ensure that no coil is exposed, to nullify shorting of the coils.

**Applying varnish on the coils**
Coat the coils with varnish after connecting all the wires and then assemble the motor. This should be done in such a way that no air pockets remain after the varnish is dry. One method to ensure this is using a Vacuum Pressure Impregnation (VPI) machine.

**Motor performance tests**
After the motor is assembled the motor is subjected to the following test to determine efficiency loss of the motor:
- No load tests
- Locked rotor test
- Reduced voltage running-up test (up to 37kW)
### 6.4 Process for repair as followed by – Authorized vs Unauthorized rewinders

*Figure 44: Difference between best practice, authorized rewinder and unauthorized rewinder*

<table>
<thead>
<tr>
<th>Steps</th>
<th>Best practices</th>
<th>Authorized rewinding</th>
<th>Unauthorized rewinding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preliminary Inspection</strong></td>
<td>• Recording basic information of the motor</td>
<td>• Recording basic information of the motor</td>
<td>• Basic information of the motor is recorded</td>
</tr>
<tr>
<td></td>
<td>• Refer to the motor related guidelines provided by the OEM</td>
<td>• Guidelines are provided by OEMs but they are often ignored</td>
<td>• Do not have any guidelines to follow for rewinding</td>
</tr>
<tr>
<td><strong>Dismantling the motor</strong></td>
<td>• Disassemble the motor on a workbench</td>
<td>• Most of them use work bench for smaller capacity motors while dismantling</td>
<td>• Depending on the size of the motor, workbench may not used</td>
</tr>
<tr>
<td><strong>Inspecting the damaged winding condition</strong></td>
<td>• Check the condition of the winding and note down the connections</td>
<td>• All the winding condition details, and the winding diagram are noted</td>
<td>• All the winding condition details, and the winding diagram are noted</td>
</tr>
<tr>
<td><strong>Removing the old winding and cleaning the slots</strong></td>
<td>• Remove the damaged winding using shear clippers after melting the varnish in heating oven, cleaning agents &amp; sandpaper.</td>
<td>• Heating ovens, cleaning agents &amp; sandpaper are used to clean the slots</td>
<td>• Flame is used to burn varnish and chisels are used to scrap old winding</td>
</tr>
<tr>
<td><strong>Winding new coils</strong></td>
<td>• Wind the coils using automated winding machine</td>
<td>• Manual process to wind the coils</td>
<td>• Manual process to wind the coils</td>
</tr>
<tr>
<td></td>
<td>• Using same gauge of wire as original</td>
<td>• Same gauge of winding wire used</td>
<td>• Few rewinders use thinner wire for winding the coils</td>
</tr>
<tr>
<td><strong>Inserting the coil into the slots</strong></td>
<td>• The new insulation paper and coils are inserted manually into the slots</td>
<td>• Insulation paper and coils are inserted manually into the slots</td>
<td>• Insulation paper and coils are inserted manually into the slots</td>
</tr>
<tr>
<td>Steps</td>
<td>Best practices</td>
<td>Authorized rewinding</td>
<td>Unauthorized rewinding</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Perform winding tests        | • Insulation resistance test  
• Measurement of stator resistance  
• High voltage test  
• Are performed on the motor | • Only few of the unauthorized rewinders perform the winding test after rewinding  
• Insulation resistance test  
• Measurement of stator resistance  
• High voltage test  
• To be performed on the winding |                                                                                  |
| Applying varnish on the coils | • Coat the coils with varnish after connecting all the wires and then assemble the motor | • Varnish is applied manually on the coils  
• Varnish is applied manually on the coils |                                                                                  |
| Motor performance tests      | Tests to be performed on the motor  
• No load test  
• Locked rotor test  
• Reduced voltage running up test (up to 37kW) | • Only no-load tests are performed on the rewinded motors that of upto 7.5 kW capacity | • Most of them only perform running test on the rewinded motors that to for small capacity motors |

Source: AGR analysis

6.5 Characteristics of Authorized and Unauthorized Rewinder

**Figure 45: Characteristics of Authorized and Unauthorized Rewinder**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Authorized rewinder</th>
<th>Unauthorized rewinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of motor</td>
<td>Depending on the working area, the authorized rewinders are permitted to rewind upto a specific frame size of motor</td>
<td>Unauthorized rewinders are free to rewind any size motor based on their capability and end-users trust</td>
</tr>
<tr>
<td>Training</td>
<td>Based on the OEMs the training is arranged annually or if there is a new model launch. However,</td>
<td>All the motors being rewinded by the unauthorized rewinders are</td>
</tr>
<tr>
<td>Parameters</td>
<td>Authorized rewinder</td>
<td>Unauthorized rewinder</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Authorized rewinder</td>
<td>rewinders show little inclination towards training</td>
<td>done using self-learnt methods and without any formal training</td>
</tr>
<tr>
<td>Rewinding procedure</td>
<td>Basic rewinding guidelines are provided to ASC. However, ASCs seldom refer to the guidelines</td>
<td>The unauthorized rewinders follow the winding diagrams and other details from the motor that has come for rewinding</td>
</tr>
<tr>
<td>Rewinding equipment</td>
<td>Manual rewinding equipment like winding jig and other tools are used for rewinding</td>
<td>Mostly the winding is done by hand, and no high-cost winding equipment is used</td>
</tr>
<tr>
<td>Copper usage</td>
<td>All ASC use original gauge of copper. However, OEM does not provide copper winding data</td>
<td>A few unauthorized rewinder change copper gauge by 0.5-1 gauge mainly in smaller size motors</td>
</tr>
<tr>
<td>Testing equipment</td>
<td>OEMs demand ASCs to be equipped with basic testing equipment. Testing report is rarely provided since end-users don't ask for it</td>
<td>Unauthorized rewinders have equipment like that of authorized rewinders</td>
</tr>
<tr>
<td>Documentation</td>
<td>The only documentation maintained by the rewinder is the log-book as it is reviewed by the OEMs annually</td>
<td>Only a book is maintained with the winding details and other parameters of the motor for future reference</td>
</tr>
<tr>
<td>Audits</td>
<td>Logbooks and equipment calibrations are checked during yearly audits</td>
<td>Unauthorized rewinders are not subjected to any such inspections other than the ones working for large scale industries on tender contracts</td>
</tr>
</tbody>
</table>

Source: AGR analysis
7 Key Recommendations

7.1 Recommendation – Industrial applications

a. Create awareness regarding preventive motor maintenance practice

Most motors installed in the industries are not subjected to preventive maintenance. It is important to conduct knowledge sharing sessions for the SMEs to make them understand the importance of simple preventive maintenance and its effect on the life (lower capex) and efficiency of motor (lower opex) in the long run.

*Impact:* Reduction in the motor failure due to periodic maintenance will increase the life of winding and motors. Therefore, reducing loss in efficiency due to rewinding.

b. Create awareness about the best rewinding practice

The industry stakeholders are not aware or concerned about the impact of current rewinding practices. Awareness program should be conducted in the industries to demonstrate the energy loss, efficiency loss and reduction in life after rewinding using improper practices. A monetary impact on capex and opex will help showcasing the saving potential of using best rewinding practices.

*Impact:* The awareness of the best rewinding practices will generate a pull for the rewinders that are following the best rewinding practices.

c. Inculcate practice of demanding test certificates from rewinders

Industries should be made aware about the importance of the test certificate. It should create a document trail to understand rewinding quality and would also help industries decide based on the economics of replacing vs rewinding motors.

The end-users should inculcate the practice of periodically checking and documenting motor related parameters like motor load, current drawn, coil resistance, insulation conditions, etc. This will create benchmark for rewinding performance.

*Impact:* The end-user will be able to track the efficiency loss of the motor and thus be able to decide whether to replace the motor with a new one or not

d. Government may conduct energy audit of key SME clusters

A large proportion of the small size LT motors are installed in the SME industry. These motors are rewinded multiple times and generally by the unauthorized rewinders. The SME industries do not conduct energy audits that can throw light on few of the most inefficient machinery and the practices.

Government could conduct a cluster-based audit and therefore identify the inefficient units. These units can be provided high efficiency IE3 motors at discounted price.
7.2 Recommendations – Agriculture Applications

a. **Create awareness about pump maintenance amongst farmers**

In most provinces, farmers either have flat payments or free electricity therefore, pumps’ efficiency is not important for them. On the other hand, pump durability and throughput are considered important within the farmers’ community.

The industry stakeholders (government, OEMs, and associations) should create awareness amongst farmers that proper rewinding increases pump throughput and improves the life of pump.

*Impact*: A shift of preference from random/local rewinders to the ASCs who are following best rewinding practices.

b. **OEMs may consider supplying a solution (incl. O&M) vis-à-vis just the product (the pump)**

Most farmers are unaware of the maintenance practice of the motors. This leads to premature failure of the pump.

OEMs (with government’s support) should develop their dealers/distributors to provide operation and maintenance (O&M) services. Therefore, ensuring higher efficiency.

*Impact*: This will help the OEMs in increasing their footprint and generate an additional source of income along with increasing their sales in the region. The solution could be marketed more attractively to the farmers.

c. **Government could subsidize farmers that buys BEE approved pumps**

Most unorganized pump manufacturers use inferior components and don’t have a quality management system in their production facility.

Government could subsidize farmers using BEE approved pumps as these motors have longer life and much higher efficiency. BEE new norms, if made mandatory, will result in more efficient pumps used by the industry.

*Impact*: The shift of small farmers towards BEE approved motors with better durability and lesser losses will reduce the energy losses being subsidized by the government.

7.3 Recommendations for implementing best practice among Authorized rewinders

a. **Providing testing reports should be made mandatory for all authorized rewinders**

Currently, most rewinders are not providing test reports. The government should mandate that all authorized rewinders should provide test certificates after rewinding. Few of the tests could be

- Winding resistance test
- Thermistor resistance test
• Megger/ HV test
• Surge test
• Load test

*Impact:* The industries can track the efficiency loss of the motor and thus be able to decide whether to replace the motor with a new more efficient IE3 motor.

b. **Automatic rewinding machine will help consistent usage of copper**

Almost all rewinders use manual/ hand rewinding method. This leads to inconsistent usage of copper. Higher overhang leads to higher efficiency loss.

OEM with the government support, could enforce mandatory installation of testing equipment, VPI (for IE3 motors), and automatic winding machine.

The rewinders must be made aware of the benefits of using automatic coil winding machine to improve the winding packaging which reduces the efficiency loss in the motor after rewinding.

*Impact:* Right size of the copper coils will reduce the copper losses in the motor.

c. **OEMs should push for mandatory training sessions**

OEMs should conduct mandatory training sessions at least once a year for all authorized rewinders so that they are well versed with the best rewinding practice. Currently, for most OEMs, the training sessions are optional. Rewinders attend these sessions mainly to visit the manufacturing facility.

*Impact:* Improvement in quality of rewinding from the authorized rewinders.

d. **An online data pool may be developed for providing winding related information**

Almost all rewinders use winding data of the motor that has come for rewinding or from an older document of the same capacity (frame size) motor. This leads to inconsistent usage of copper and greater efficiency losses.

The industry could develop an online data bank which can be accessed by all the rewinders. The data bank may consist of motor model specific information like winding diagrams, copper gauge, coil length, etc.

*Impact:* This will create transparency between the rewinders and the OEM and hence improve the overall winding quality of the rewinders.

7.4 **Recommendations for implementing best practice among unauthorized rewinders**

a. **Providing best practice certification from government bodies to both authorized and unauthorized rewinders**

Currently, no industry stakeholder is responsible of maintaining and regulating the unauthorized rewinders in the market.

Government bodies like BEE can certify the rewinders based on parameters like:
• Adoption of BEE rewinding guidelines
• Capabilities (frame size and OEMs catered)
• Equipment used for rewinding
• Ability to provide testing report

Impact: It will help the users of industry to freely choose the BEE approved rewinders.

b. Lack of training facilities for unauthorized rewinders

The unauthorized rewinders are rewinding motors based on their work experience or by the methods taught by their senior colleagues. They are not trained by motor rewinding experts or professionals. Under Skill India program, the government can develop and support training sessions for such untrained rewinders. This training can be conducted on a regional/district level in the ITI or other skill centers located in the vicinity.

Impact: Energy losses, ~12,000 Cr per annum, will be reduced for LT motors and agriculture pumps, as unauthorized rewinders are the preferred choice.

c. Government should set-up central testing facilities in industrial clusters to confirm the quality of rewinding

India should promote setting-up of testing facilities in the industrial clusters, to confirm the motor efficiency. This will help the industries in decision making regarding rewind vs buy.

7.5 Recommendations for ceiling fan replacement instead for rewinding

There are substantial savings if end-user replaces their regular fan with BEE 5 Star rated fan. Using a BEE 5-star fan one can save INR 1,700-1,800 in three years covering the cost of branded BEE 5-star rated fan.

<table>
<thead>
<tr>
<th>Type of ceiling fan manufacturer</th>
<th>kW rating of motor</th>
<th>Average life of motor after rewinding (Years)</th>
<th>Average no. of rewinding</th>
<th>Extra cost for running a motor after rewinding Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branded</td>
<td>0.075</td>
<td>3</td>
<td>2</td>
<td>281 (1), 593 (2), 281 (3), 281 (4) 874</td>
</tr>
<tr>
<td>Unbranded</td>
<td>0.075</td>
<td>1.5</td>
<td>4</td>
<td>140 (1), 297 (2), 471 (3), 667 (4) 1575</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of ceiling fan manufacturer</th>
<th>Rating of BEE 5-star fans (KW)</th>
<th>Average life of motor after rewinding (Years)</th>
<th>Average no. of rewinding</th>
<th>Savings by replacing regular fan with BEE 5-star fan instead of rewinding Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branded</td>
<td>0.055</td>
<td>3</td>
<td>2</td>
<td>1704 (1), 2017 (2), 1183 (3), 1379 (4) 3721</td>
</tr>
<tr>
<td>Unbranded</td>
<td>0.055</td>
<td>1.5</td>
<td>4</td>
<td>852 (1), 1008 (2), 1183 (3), 1379 (4) 4422</td>
</tr>
</tbody>
</table>

OEMs should promote the shift towards BEE 5-star rated fans by providing exchange offers over regular fan so that the end-user can replace them with efficient fans instead of rewinding.
7.6  Recommendations for LT Induction motor replacement instead for rewinding

There are substantial savings if end-user replaces their old LT Induction motor with IE3 motor.

**Market Dynamics**

<table>
<thead>
<tr>
<th>kW rating of motor</th>
<th>Average life of motor after rewinding (Years)</th>
<th>Average no. of rewinding</th>
<th>Extra cost for running a motor after rewinding</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>2.1</td>
<td>6.0</td>
<td>8257 16769 25549 34609 43962 53625</td>
<td>182772</td>
</tr>
<tr>
<td>315</td>
<td>3.6</td>
<td>3.0</td>
<td>57648 117080 178379</td>
<td>353108</td>
</tr>
</tbody>
</table>

- The total cost of operating a motor after 3rd rewinding for 7.5 KW and 2nd rewinding in 315 KW, will exceed the cost of a new IE3 motor which is sold around 36k and 559k respectively.

So, for end-users it is better to replace the old motors by new IE3 motors, before 3rd rewinding for 7.5 KW and before 2nd rewinding 315 KW motor.

**Action Plan**

- OEMs should promote the shift towards IE3 motors by providing the cost savings achieved if old motors are replaced instead of rewinding.

*Impact:* Rapid increase in penetration of energy efficient IE3 motors will result in saving for the industrial and agriculture applications.
8 Annexure

Key assumptions considered for the study

8.1 Industrial applications:

- Average kW per unit of motor (kW/unit):^{20}
  - Upto 7.5 kW: 2.15
  - 9.3 to 37 kW: 13.90
  - 45 to 280 kW: 70.43
  - >280 kW: 531.33

- Motor efficiency:^{21}
  - IE1: 85.49%
  - IE2: 88.08%
  - IE3: 89.89%
  - Weighted average efficiency: 86.1%

- Operating hours per annum:^{22}
  - Large Industries: 7,200 hours (Motor running 3 shifts i.e. 24 hrs. a day for 300 days)
  - Medium Industries: 5,400 hours (Motor running 2 shifts i.e. 16 hrs. a day for 300 days)
  - SMEs: 3,000 (Motor running 1 shift i.e. 10 hrs. a day for 300 days)
  - Average: 5,200 hours

- Efficiency drop after each rewinding:^{23}
  - Authorized rewinding: 1.0%
  - Unauthorized rewinding: 1.5%
  - Best practice rewinding: 0.5%

- GHG emissions per unit of electricity consumed (kg/kW):^{24} 0.9kg (considering 100% of electricity generation is from coal)

8.2 Agriculture applications:

- Average kW per unit of motor (kW/unit):^{25}
  - <2.2kW: 1.03
  - 3.7kW: 3.73
  - 5.5kW: 5.59
  - 7.5kW: 7.46
  - 11kW: 11.19

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^{20} IEEMA Production data 2010-2019
^{21} Efficiency Values of 3 Phase Induction Motors (as per IS 12615)
^{22} Discussion with industry expert and end-users
^{23} Discussion with rewinders, EELS & AGR estimations
^{24} Source: Rensmart and UK Parliamentary Office of Science and Technology - [https://www.rensmart.com/Calculators/KWH-to-CO2](https://www.rensmart.com/Calculators/KWH-to-CO2)
^{25} Discussions with Dealers, rewinders and OEMs, and Market Research of Agriculture Pump-sets Industry of India - Shakti Sustainable Energy Foundation
• Share of pump motor sales by capacity:
  - <2.2kW: 20%
  - 3.7kW: 35%
  - 5.5kW: 25%
  - 7.5kW: 10%
  - 11kW: 10%

• Efficiency of motor:
  - Weighted average efficiency: 80.7%

• Efficiency drop after each rewinding:
  - Authorized rewinding: 1.0%
  - Unauthorized rewinding: 1.5%
  - Best practice rewinding: 0.5%

• Operating hours per annum:
  - Average: 2,300 hours

8.3 Housing fan applications:

• Manufacturer segment share in ceiling fan installed base:
  - Branded fan manufacturer: 75%
  - Local fan manufacturer using copper winding material: 8%
  - Local fan manufacturer using aluminium winding material: 18%

• Average KW per unit of motor (kW/unit):
  - Regular fan: 0.075kW
  - Exhaust fan: 0.040kW

• Efficiency drop after each rewinding:
  - Unauthorized rewinding: 5%
  - Best practice rewinding: 0.5%

• Operating hours per annum:
  - Ceiling fan: 3,600 hours
  - Exhaust fan: 1,825 hours

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26 Hp to kW conversions
27 Discussion with industry expert
28 Discussion with rewinders, EELS & AGR estimations
29 Discussion with rewinders and end-users
30 Discussions with industry experts
31 Discussion with rewinders
32 Discussion with rewinders, EELS & AGR estimations
33 Discussion with rewinders and end-users
9. International Copper Association India

About ICA and Copper Alliance

ICA and the Copper Alliance™ are responsible for guiding policy and strategy and for funding international initiatives and promotional activities for promoting beneficial use of copper based on its superior technical performance and its contribution to a higher quality of life worldwide. Headquartered in Washington D C., the organization has regional offices in Brussels, New York, Santiago, and Shanghai.

ICA was set up in 1959 and it runs programs and initiatives in more than 60 countries through its regional offices and 31 copper promotion centres. This network of global copper centres and industry leading members have been unified under a common brand and visual identity referred to as Copper Alliance™.

About International Copper Association India (ICA India)

The International Copper Association India (ICA India), a member of Copper Alliance and the Indian arm of the International Copper Association Limited (ICA) formed in 1998, a not for profit, non-commercial organization, which, as a part of its social activity, works to promote electrical safety, Power Quality and energy efficiency. ICA India has been working with all concerned stakeholder like Govt agencies, Regulators, Industries and end users to provide required technical support for the development of policies/standards/regulation and their implementation. ICA India works closely with concerned bodies like BIS, BEE, CEA, RERA, EESL and various other departments under Govt of India.

Program and activities of ICAI

ICA India conducts various programs employing a mix of market development and regulation advocacy approach to encourage use of best material standard for achieving sustainable objectives through its various initiatives such as:

- Encourage safe wiring practices in the buildings
- Increase awareness of power quality through Asia Power Quality Initiative Platform
- Propagate use of energy efficient motors for energy savings in industries
- Promote use of high efficiency motors and pumps in the agricultural sector
- Promote use of superior microgroove copper tube heat exchangers technology to OEMs and super-efficient ACs for users
- Encourage use of energy efficient appliances by promoting star labelling program
- Reduce distribution losses in the power sector through use of low loss distribution transformer
- Encourage renewable energy technologies like solar water heaters, solar pump etc.

ICA India drives its initiatives through seminars, workshops and training programs across India in collaboration with Industry Associations, institutions and trade bodies. It also publishes technical handbooks, information booklets and brochures aimed at spreading general awareness on the beneficial use of Copper. The organization receives support from its global-level members and from major Indian copper producers, fabricators, cable and wire manufacturers and EE motor manufacturers.