



## **United Nations Development Programme**

**Ministry of Power – Bureau of Energy Efficiency  
Government of India**

### **UNDP/GEF Project: Achieving Reduction in GHG Emissions through Advanced Energy Efficiency Technology in Electric Motors (AEETEM)**

(PIMS 3489)

## **Final Evaluation Report**

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## ABBREVIATIONS

| Acronym | Meaning  |
|---------|--|
| ADB     | Asian Development Bank   |
| AEETEM  | “Advanced Energy Efficiency Technology in Electric Motors” Project |
| APR     | Annual Progress Report   |
| AWP     | Annual Work Plan   |
| BEE     | Bureau of Energy Efficiency  |
| BIS     | Bureau of Indian Standards   |
| CER     | Certified Emission Reductions                                      |
| CFC     | Common Fund for Commodities  |
| CMR     | Copper motor rotor   |
| DANIDA  | Danish International Development Agency                            |
| DPD     | Deputy Project Director  |
| DSM     | Demand Side Management   |
| EC&EE   | Energy Conservation and Energy Efficiency                          |
| ETC     | Enabling Technology Center   |
| ESCO    | Energy Service Company   |
| FE      | Final Evaluation   |
| GEF     | Global Environmental Facility                                      |
| GHG     | Greenhouse Gases   |
| GoI     | Government of India  |
| GWh     | Gigawatt-hour  |
| ICA     | International Copper Association                                   |
| ICSG    | International Copper Study Group                                   |
| ICPCI   | International Copper Promotion Council (India)                     |
| IEC     | International Electrotechnical Commission                          |
| kWh     | Kilowatt-hours   |
| MDG     | Millennium Development Goals                                       |
| MoP     | Ministry of Power  |
| MRV     | Monitoring, reporting and verification                             |
| NFTDC   | Non-Ferrous Materials Technology Development Center                |
| SME     | Small to Medium Enterprises  |
| MTE     | Mid-Term Evaluation  |
| mTOE    | Million tonnes of oil equivalent                                   |
| NGOs    | Non Government Organizations                                       |
| NPD     | National Project Director  |
| NPM     | National Project Manager   |
| OEM     | Original equipment manufacturers                                   |
| PB      | Project Board  |
| PDF-B   | Project Development Fund – Block B                                 |
| PIR     | Project Implementation Review                                      |
| PM      | Project Manager  |
| PMU     | Project Management Unit  |
| PSC     | Project Steering Committee   |
| QPR     | Quarterly Progress Report  |
| QWP     | Quarterly Workplan   |

| <b>Acronym</b> | <b>Meaning</b>                       |
|----------------|--------------------------------------|
| R&D            | Research & Development               |
| SMEs           | Small and Medium Enterprises         |
| TA             | Technical assistance                 |
| TOE            | Tonnes of Oil Equivalent             |
| TCE            | Tonnes of Coal Equivalent            |
| ToR            | Terms of Reference                   |
| TT             | Technology Transfer                  |
| TTA            | Technology Transfer Agreement        |
| UNDP           | United Nations Development Programme |
| VDC            | Vertical die-cast                    |
| WB             | World Bank                           |

## EXECUTIVE SUMMARY

### Background

India's growing energy consumption leaves the country vulnerable to energy shortages. The Indian industrial agricultural sectors account for over 35% of country's primary energy consumption that was 263 mTOE in 2011. The Bureau of Energy Efficiency (BEE) under the Ministry of Power has undertaken a number of energy efficiency programs designed to reduce this energy consumption and reduce the country's reliance on imported fossil fuels. One of these is a labelling program for induction motors under the Energy Conservation Act 2001. For the most recent Bureau of Indian Standards (BIS), the approved standard is IS 21615-2011, designed to harmonize with the IEC 60034-1 standard of 2008 classifying IE1-Standard efficiency, IE2-High efficiency (EFF1), IE3-Premium efficiency levels.

Small motors (<100 HP or 75 kW) dominate the motor market in India. These motors are used in various manufacturing sectors as well as for irrigation pumping in the agricultural sector. In the industrial sector, most of these motors are fully loaded for more than 3,000 hrs annually (roughly 11 hrs for 333 days each year). Hence, a market transformation of the small motors market will result in significant energy savings for India.

The issue, however, has been the rate of compliance to new standards and the ability of the motor manufacturing sector to employ a range of improvements in materials, design and manufacturing methods and quality control that collectively reduce the motor's losses. In 2008 prior to the commencement of AEETEM, feedback from the manufacturers indicated that the sale of energy efficient motors (rated as EFF1) was approximately 2% of the total sales. The major reason cited for low sales was the higher initial cost of the EFF1 motors.

Since 2006, ICA through its local Indian affiliate ICPCI, was promoting the use of copper rotors that would provide a 3 to 4% efficiency improvement of a motor in comparison to the predominant aluminium rotor motors. This efficiency can be attributed to the comparative properties of the two metals: copper is a better conductor of electricity, which results in less loss and heating of the copper coil during operation and thus less cooling required for copper rotor motors. This would also result in doubling the service life of the motor over aluminium rotor motors due to the aging of insulation. Moreover, the usage of copper instead of aluminium in the induction motor rotor leads to an overall size reduction of the motor. Based on the relative prices of copper, aluminium and electrical steel at the time the project was proposed, the size reduction was expected to result in a significant reduction of overall material costs for high efficiency motors, making these more affordable, thus stimulating demand.

A further expectation of the project was the rapid introduction by BEE of mandatory minimum efficiency performance standards (MEPS) for motors at the IE1 level (as this had already been adopted by major motors manufacturer members of IEEMA as a self-imposed minimum) as well as the demand pull through labelling of IE2 motors and promotional efforts.

In 2006, the major issue of copper rotor motor technologies, however, was how to accelerate its adoption within the motor manufacturing sector in India. The manufacture and sales of small motors for the Indian market are dominated by SMEs clustered in many

of India's larger cities such as Surat, Ahmedabad, Coimbatore and Delhi to name a few. Most of these original equipment manufacturers (OEMs) are SMEs with small workshops where motors are made by hand. The existence of SMEs within clusters fosters learning amongst the SMEs and improves their manufacturing performance.

The awareness of the benefits of copper rotors amongst these SMEs is also due to their volume of work to service the motors market (i.e. textile mills, appliance manufacturers, pump motor manufacturers, diamond cutting). These SMEs, however, traditionally operate on thin margins and seeks lowest cost solutions to minimize operational costs. This place SMEs servicing the small motors market in a difficult position: they need to minimize their own operational costs while improving their motors to comply with the new standards without increasing prices of their product. As a result, a portion of the small motors market can be classified as an "informal" industry where a number of SMEs cannot access any finance to improve their businesses.

The project development **goal** is to introduce technology for high pressure copper die casting for manufacturers of copper rotors and electric motors to achieve energy savings.

To achieve this goal, the Project was designed with a number of expected **project outcomes**:

- Outcome 1: An enabling technology center has been set up and is fully functional;
- Outcome 2: Copper motor rotor (CMR) technology has been assimilated and upgraded;
- Outcome 3: CMR technology has been transferred and commercialized.

## Context and Purpose of the Final Evaluation

The purpose of the FE for this Project is to evaluate the progress towards the attainment of global environmental objectives, project objectives and outcomes, capture lessons learned and suggest recommendations on major improvements. The FE is to serve as an agent of change and play a critical role in supporting accountability. As such, the FE will serve to:

- promote accountability and transparency, and to assess and disclose levels of project accomplishments;
- synthesize lessons that may help improve the selection, design and implementation of future GEF activities;
- provide feedback on issues that are recurrent across the portfolio and need attention, and on improvements regarding previously identified issues; and,
- contribute to the GEF Evaluation Office databases for aggregation, analysis and reporting on effectiveness of GEF operations in achieving global environmental benefits and on the quality of monitoring and evaluation across the GEF system.

**Table A: Summary Assessment of Project Outcomes and Sustainability**

| Project Objectives   | Intended End of Project targets (from re-constructed project planning matrix from 2007)   | Outcome <sup>1</sup> Assessment<br>(Rel=Relevance, Eff=Effectiveness Efy=Efficiency Ov=Overall Rating) | Sustainability Assessment <sup>2</sup> | Actual End-of-Project (EOP) Outcomes (as of 30 April 2012)   |
|--|---|--|--|--|
| <p><b>Goal:</b> Introduce technology for high pressure copper die casting for manufacturers of copper cast rotor and electric motors to achieve energy savings</p> | <p>Increase market share of high efficiency copper rotor motors through technology transfer and commercialization with supporting market development activities; market penetration rate of 3% after 3 years and 20% after 10 years</p> | <p>Rel – S<br/>Eff - MS<br/>Efy - MS<br/>Ov – MS</p>   | <p><b>Moderately Likely</b></p>        | <p><i>Currently, high efficiency CMRs have not reached the market. Basic reasons for this are the fact that technology transfer and commercialization of CMR technology has not been fully completed. However, the pilot production of CMRs has generated a sample size of CMRs from which the die-casting process can be tweaked to ensure replicability of consistent production of quality CMRs. The Evaluation Team estimates that full commercialization of the CMR technology will take another 4 years at the current pace of development. This would result in cumulative indirect emission reductions of 4.135 million tonnes of CO<sub>2eq</sub> ten</i></p> |

<sup>1</sup> *Highly Satisfactory (HS)*: The project has no shortcomings in the achievement of its objectives; *Satisfactory (S)*: The project has minor shortcomings in the achievement of its objectives; *Moderately Satisfactory (MS)*: The project has moderate shortcomings in the achievement of its objectives; *Moderately Unsatisfactory (MU)*: The project has significant shortcomings in the achievement of its objectives; *Unsatisfactory (U)*: The project has major shortcomings in the achievement of its objectives; *Highly Unsatisfactory (HU)*: The project has severe shortcomings in the achievement of its objectives..

<sup>2</sup> *Likely (L)*: very likely to continue and resources in place; *Moderately Likely (ML)*: model is viable, but funding or resources may not be in place; *Moderately Unlikely (MU)*: model is not viable or needs changing; and/or resources not in place; and *Unlikely (U)*: model is not viable and resources are not in place.



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|---|---|--|--|--|
|   |   |  |  | <i>years after completion of the Project.</i>  |
| <b>Outcome 1:</b> Enabling Technology Centre has been set up and is fully functioning | ETC is built and functioning<br>Physical commencement of operations of the proposed ETC. (Within 1 year post project launch)  | Rel – HS<br>Eff – S<br>Efy – S<br>Ov – S   | <b>Moderately Likely</b>               | <i>The ETC was built and functional as of August 2008 using mainly funds from Common Fund for Commodities (CFC)</i>                                  |
|   | Physical installation of plant and equipment (within 1 year post project launch). Designing and fabricating furnace and other subassemblies including die inserts for copper die casting will be the main goal under the activity. Successful fabrication will lead to cost effective commercialization of the process. |  |  | <i>The physical installation of the CMR technology (the VCD50 press) in its own building had occurred in August 2008</i>                             |
| <b>Outcome 2:</b> CMR Technology has been assimilated and upgraded                    | Successful results on pilot batches of cast copper rotors (at least two rotor sizes). (within two years post project launch)<br>Successful trials on two rotor  | Rel – S<br>Eff – MS<br>Efy – MS<br>Ov – MS   | <b>Moderately Likely</b>               | <i>The first pilot CMR batches were produced in May 2010. Since then, more than 18 rotor sizes and models have been manufactured for over 9 OEMs</i> |

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|---|---|--|--|---|
|   | <p>sizes / models will lead generating at least 5 enquiries from manufacturers</p> <p>Successful alliance formed with at least two manufacturers (within two years post project launch)<br/>Approximate size of manufacturing capacity expected to be installed for copper rotor manufacture.</p> |  |  | <p><i>Two alliances are being planned, one with an industrial cluster and the other with a private OEM</i></p>  |
| <p><b>Outcome 3:</b> Technology has been transferred &amp; commercialized</p> | <p>Arrange visits of motor manufacturers to ETC &amp; demonstrate technical feasibility for copper die-casting</p> <p>Signed technology transfer agreements (at least with two manufacturers) (Within 3 years post project launch)</p>  | <p><b>Rel – MS</b><br/><b>Eff – MS</b><br/><b>Efy – MU</b><br/><b>Ov – MS</b></p>                        | <p><b>Moderately Likely</b></p>        | <p><i>There have been visits to a large number of OEMs. Project personnel, however, were unable to indicate if this represented over 60% of the motors market in India</i></p> <p><i>Two TT agreements are being planned now with Happy Engineering (Surat) and Mehala Machinery (Coimbatore). The TT agreements, however, have not been signed as the OEMs are awaiting consistent production of quality CMRs from NFTDC pilot batches</i></p> |

**Table A: Summary Assessment of Project Outcomes and Sustainability**

| Project Objectives | Intended End of Project targets (from re-constructed project planning matrix from 2007)   | Outcome <sup>1</sup> Assessment<br>(Rel=Relevance, Eff=Effectiveness, Efy=Efficiency, Ov=Overall Rating) | Sustainability Assessment <sup>2</sup> | Actual End-of-Project (EOP) Outcomes (as of 30 April 2012)   |
|--------------------|---|--|--|--|
|                    | At least 10 letters of enquiries from end users and OEMs (Within 3 years post project launch) as result of market development programs and awareness building exercise. |  |  | <i>There have been a total of 13 letters of enquiries from OEMs on the press for CMRs</i>                                |
|                    | At least one Bank / financing agency launches a scheme to promote new high efficiency motors / products. (Within 3 years post project launch)                           |  |  | <i>No financing institutes have yet been involved with the launch of a EE motors scheme involving the VDC technology</i> |

## Assessment of Project Outcomes and Sustainability

The overall rating of the project results is marginally satisfactory (MS). This is based on the Project the following outcomes:

- a fully functional enabling technology center has been established at NFTDC;
- CMR technology has been assimilated with a number of alliances that are being formed contingent on the technology being able to produce consistent copper rotors without blow holes
- the market for copper motor rotors has been developed by the Project; however, the technology has not been yet commercialized due to the CMR technology at NFTDC being used for several die-cast designs (for different applications) resulting in a lack of time to develop the protocols for producing consistent high quality copper rotors.

Factors that have hindered the project to meet all of its intended outcomes include insufficient time and project resources to provide a commercial scale copper rotor press. SME clusters can replicate the service to a large number of SMEs who are making small motors for the Indian small motors market.

The overall Project sustainability rating is moderately likely (ML). This rating is primarily based on:

- Strong Gol support for increasing the efficiency of electric motors made in India;
- Strong market demand created by ICPCI amongst SME rotor manufacturers who currently are making copper rotors by hand (which is time consuming), and are unable to meet demand (through government pressure) for the sale of increased energy efficient motors as per BIS Standard IS12615: 2011;
- The knowledge and capability of NFTDC to overcome the issue of inconsistent production quality if they had an appropriate level of resources;
- The lack of full commitment to providing appropriate resources to transfer technology to candidate industry clusters pending resolution of the issues on consistent quality production of CMRs;
- The paucity of resources to build capacity of NFTDC to provide the necessary technical support and sustained production of CMRs within the industry clusters.

### Replicability or Catalytic Role of Project

The Project has played a catalytic role in stimulating the interest in CMR technology, a cost-effective manufacturing method that would reduce the cost of EFF1 motors, increase the market penetration of these motors, and reduce energy consumption. In 2006, NFTDC provided an alternative by designing a vertical die cast process similar to the ones used for die casting aluminium rotors in India. Financing for developing NFTDCs new process was provided by CFC in 2006. GEF funds were provided under the AEETEM project in August 2008 to market NFTDCs CMR technology to the SMEs manufacturing small motors and end-users of the motors.

Since May 2010, NFTDC had produced 427 CMRs of varying sizes and lengths for a number of SME clients. The CMR technology development is now at a stage where further pilot batches are required to reach a state where there is consistent production of quality CMRs. Replicability potential of the CMR technology is significant based on the lower production cost of CMR rotors from the VDC50 press; this potential, however, cannot be realized until the issues on consistently producing quality CMRs are resolved.

## **M&E During Project Implementation**

Ratings of the Project's Monitoring and Evaluation system<sup>15</sup> are as follows:

- Quality of M&E design – S;
- Quality of M&E implementation – S.

## **Assessment of Processes Affecting Attainment of Project Outcomes and Sustainability**

### Preparation and Readiness:

The AEETEM design assumed that the project resources and a 3-year implementation period were sufficient to commercialize the technology. These assumptions underestimated the time and effort required to optimize the production process of CMRs to the extent that it could be commercialized into some of the motor industry clusters.

The stakeholders were certainly ready for the project. NFTDC received funding from CFC in 2006 to develop its CMR technology, and commenced R&D in 2008 around the start of AEETEM. ICPCI already had a large network of SME industrial associations and small motor manufacturers, and had already made contact with a number of these associations and OEMs. In conclusion, the primary stakeholders, ICPCI and NFTDC, were in a high state of readiness for AEETEM.

### Country Ownership and Drivenness:

BEE has undertaken a proactive role in supporting this project. NFTDC, the autonomous government agency in Hyderabad have been an excellent proactive host of their CMR technology.

### Stakeholder Involvement:

The main stakeholders of the Project, ICPCI and NFTDC, were strongly engaged in activities towards commercialization of CMR technology. Industry associations and OEMs were engaged by ICPCI through workshops and personal contacts specifically in motor manufacturing clusters in Surat, Delhi and IEEMA whose membership covers a

<sup>15</sup> HS or Highly Satisfactory: There were no shortcomings in the project M&E system;  
 S or Satisfactory: There were minor shortcomings in the project M&E system,  
 MS or Moderately Satisfactory: There were moderate shortcomings in the project M&E system;  
 MU or Moderately Unsatisfactory: There were significant shortcomings in the project M&E system;  
 U or Unsatisfactory: There were major shortcomings in the project M&E system;  
 HU or Highly Unsatisfactory: The Project had no M&E system

large geographical area of India. Their interest had been raised by the prospect of the Project providing them with quality copper rotors that would increase their sales and enable them to meet the voluntary compliance standards of IE4.

#### Financial Planning:

AEETEM was planned as a 3-year project; as such, the GEF resources of USD 250,000 was managed by ICPCI and was used mainly to provide marketing support of the CMR technology to the various vendors and manufacturers of CMRs throughout India. The evaluation team, however, is of the opinion that the USD 250,000 was certainly not sufficient to meet the objectives of the project. Additional funds would have helped the project to achieve an interim goal of consistent quality of CMRs and an earlier date of commercialization of the CMR technology.

#### Supervision and Backstopping by UNDP:

Supervision and backstopping efforts by UNDP India and the UNDP-GEF Regional Office in Bangkok were satisfactory. For a project of this size, there were few if any issues related to implementation of the project; the issues were mainly related to how the Project could meet its intended objectives within the Project timeframe.

#### Co-Financing and Delays:

The Project co-financing amounts were estimated to be in the order of USD 1.642 million, roughly six times the GEF allocation. Prior to the commencement of the Project, co-financing was already committed from CFC. During the course of the Project, significant in-kind contributions were provided by ICPCI, NFTDC and BEE.

Delays in reaching AEETEM's outcome of commercialization of the CMR technology are mainly related to the business arrangements between the OEMs and NFTDC, the large number of lamination designs and stampings, and the lack of responsiveness of the OEMs to the changes in the casting process. The arrangements for pilot rotor die-casting were as follows:

- OEMs would provide to NFTDC the rotor design parameters (i.e. dimensions of end rings, core length, skew angle, if any, and quantity) and supply the laminations complete with their unique stamping design;
- NFTDC would provide the services to design the tools for die-casting, fabrication of the tools, stacking of the rotors to a desired length, die-casting the rotors, and machining the rotors for cleaning and exact dimensioning;
- NFTDC would return the rotors to the OEM for quality testing;
- OEMs would test the pilot batches which were often found to have "blow holes" that affect the efficiency of the rotors;
- The OEM would then provide this feedback to NFTDC for the casting of another pilot batch, using lessons learned from the first pilot batch.

The problems with this arrangement highlight the need for better engagement between the OEMs and SMEs in the rotor manufacture business; this would have involved having NFTDC in charge of the design and stamping supplies during the development of the

VDC process for a particular stamping design; this would have accelerated NFTDC to manufacture CMRs of consistent quality.

## Lessons Learned

Lessons learned from AEETEM pertain mainly to the requirements for the successful design of a project involving commercialization of a new technology. Global experience indicates that at least 5 years are required before commercialization of many technologies in the manufacturing and environmental sectors. As such, similar projects should be planned with sufficient resources for:

- An appropriate pilot phase for a new technology. In the case of AEETEM, a “trial” casting phase was required to optimize the copper die-cast process, understand the behaviour of molten copper in the VDC and develop the tools and procedures for casting copper rotors with minimal gas entrapment in the copper casting or the elimination of “blow holes”. The lesson learned from AEETEM is that careful design of the pilot phase framework is required prior to commercialization; this would include the actual business arrangements to prove the viability of the technology to be commercialized, and the time and personnel resources required to manage the commercialization aspects within a set time frame;
- Appropriate capacity building activities that involve the assimilation of new technologies with SMEs. The lesson to be learned from AEETEM is that technology assimilation where SMEs are the target group need to be designed with an appropriate level of SME assistance that minimizes their opportunity costs; this would include awareness raising activities located close to the SMEs (in clusters) or compensating the SME for the opportunity costs when attending these events;
- Understanding and overcoming the complexities of the supply chain in an informal sector. A lesson learned from AEETEM is that closer attention to the business arrangements between NFTDC and the SMEs would have mitigated the slow pace of progress in attaining consistent production of quality CMRs. An improved business arrangement would have included a dedicated NFTDC person who would be proactive in the management of the pilot production of CMRs, improving the promptness of feedback from the OEMs on the quality of the CMR batches, and an earlier date in which quality CMRs would have been produced. Another improvement in business arrangements would have been for NFTDC to be in charge of CMR designs from OEMs that would have brought some degree of standardization to the design process.

## Recommendations

Without further external resources, commercialization of CMR technology will likely not occur for another 5 years. As it is the stated intention of the Indian government to accelerate the use of EFF1 motors throughout India’s industrial sector, further resources will be required to accelerate commercialization of the CMR technology to reach a target

of 3% market penetration within 3 years from the end of the project. The following recommendations are made on this basis:

**Recommendation 1: Clarify NFTDCs future role in rotor manufacturing.** NFTDC future role in this sector appears to be best suited to the development of new rotor designs and the dissemination of such designs to the OEMs:

- NFTDC should be the lead agency to develop the manufacturing procedures for die-casting new CMR designs using the VDC press. As changes to lamination patterns in the stampings hold the key to future efficiency gains in rotor designs, NFTDC's patented CMR technology has the versatility to die-cast any lamination designs that would provide maximum energy savings to a particular rotor design;
- NFTDC can disseminate information on the use of its CMR technology and carve its market niche in being one of the only entities that has a technology for the die-casting of copper rotors adapted to Indian conditions;
- NFTDC can transfer and support its CMR technology use to SME clusters or OEMs under a licensing arrangement. This arrangement would include a fee for NFTDC for technology transfer and a long-term technical support agreement to CMR technology users. The technical support agreement should include rotor design changes to meet future changes in motor standards to IE5 and beyond;
- NFTDC should offer services to design and implement retrofits for adopting existing aluminium die cast presses in the industries for casting copper rotors. This can reduce the cost of investment.

**Recommendation 2: Clarify ICPCI's future role in CMR promotion.** ICPCI's future role on the promotion of CMRs in this sector appears best suited to:

- the concentrated marketing of CMRs and NFTDC's VDC process due their mobility and network of contacts in the motor manufacturing sector;
- disseminating the benefits of the VDC process in terms of its flexibility to manufacture numerous rotors designs that will allow them to easily improve rotor designs for future generations of rotor improvements;
- facilitate technology transfers from NFTDC to the OEMs and SME clusters. Given that NFTDC is a design and research institute, ICPCI can be the agent for transfer of VDCs to the OEMs and SME clusters including the licensing arrangements, legal matters and fund transfers. This would also offload some of the business aspects of technology transfer from NFTDC who are likely inclined to focus on design and research projects, and accelerate market transformation (as opposed to NFTDC undertaking such tasks);
- facilitating linkages with a technology accreditation center and NFTDC with regards to technical developments and new rotor standards (see Recommendation 5);
- providing advance knowledge and strategic advice to OEMs and SME clusters on upcoming legislative changes by the Gol on improving EE1 motor standards;
- monitoring transformation of motors market and the impact of EE motor sales on energy consumption and GHG emissions (see Recommendation 6).

**Recommendation 3: Strengthen human resources at NFTDC.** The specifics for human resource strengthening will entail the following aspects:

- Provide additional full time staff at the ETC to provide the necessary follow-up on feedback from OEMs on the quality of pilot CMR batches including:
  - a full time marketing person within NFTDC or a dedicated person from ICPCI who is employed to focus on the follow-up with OEMs on specific



- quality testing of pilot rotors, coordinating with OEMs on follow-up actions, and providing direction to NFTDC engineers on the specific problems and mitigating actions to improve the production consistency of quality CMRs from pilot batches;
- o three process engineers to design alternative process protocols for die-casting of each copper rotor design;
- Develop a roster of high level consultants to design and disseminate certain standards in rotor design. The consultants will be involved with:
  - o Provisions of rotor designs that meet required minimum energy performance requirements and provide some standardization to the industry that is dominated by a lack of standards within an informal SME sector;
  - o advising NFTDC on the adaptability of the CMR technology to future changes in motor efficiency standards, most notably to IE4 standards which the GoI may implement in 2014 or 2015; and
  - o advising NFTDC on its long-term role in advancing motor energy efficiency beyond IE4 standards (see Recommendation 4);
- Provide training programs to NFTDC personnel to maintain fresh approaches to new motor designs. These programs should be a link to NFTDC and assist them in disseminating to the motor manufacturing sector evolving global best practices on increasing energy efficiency and conservation in motor designs.

**Recommendation 4: Strengthen the industrial clusters to improve their assimilation of CMR technology and new motor designs.** This will involve:

- Harmonizing, standardizing and optimizing rotor designs that will improve NFTDCs ability to produce consistent quality CMRs for the OEMs. NFTDCs consultants will need to develop a suite of die-casting procedures for certain rotor designs. As such, OEMs can then select certain rotor designs that NFTDC has the ability to produce quality rotors on a consistent basis. Once NFTDC consistency has been achieved, the CMR technology would be ready for transfer to an OEM or industry cluster;
- Having NFTDC engineers working closely with OEMs or industry clusters to design rotors within standards set by NFTDC consultants. Standardized rotor designs done by OEMs and industry clusters will have better acceptance and will enable to the industry to increase its production of better EFF1 motors;
- Increasing the strength of small motor cluster associations: Since most of the industry is comprised of SMEs, their opportunity costs to improve the quality of motor production are high. Future project assistance should provide the necessary resources for these small motor industry associations to attend workshops and technology demonstrations that will assist them in changing their methods of production towards EFF1 motors. It is noted here that the GoI have a number of programs designed to provide the capital costs for technology transfer of the CMR technology, notably in Gujarat; however, the capacity of the industry associations and the SME-OEMs is insufficient to prepare the proposals necessary to access these financial assistance packages.

**Recommendation 5: Provide technical development and standards to an equipment accreditation center for the design of small motors.** This will involve transfer of applicable standards and technical knowledge developed by NFTDC to the accreditation center to regulate the production of EFF1 motors. The strengthening of

such a center will improve the industry's ability to produce EFF1 motors on a consistent basis and improve India's competitiveness with global markets for small motors.

**Recommendation 6: Build MRV capacity of ICPCI or an appropriate entity to monitor GHG reductions resulting from the market penetration of CMRs in small motors.** The development of a reliable MRV system for the market transformation of small CMR motors may attract climate funds or other concessional funding sources. ICPCI would appear to be best positioned to undertake such a role due to their contacts with various industry actors in the small motors business sector. Building of MRV capacity will require the development of a sales database, protocols for ensuring reliable sales data and usage of the EFF1 motors, and training of personnel to enter and manage this data. This will raise the confidence of GHG reductions from market penetration of CMRs and attract climate funds.

# 1. INTRODUCTION

This report summarizes the findings of the Final Evaluation Mission conducted during May 2012 for “Achieving Reduction in GHG Emissions through Advanced Energy Efficiency Technology in Electric Motors” (herein referred to as the “Project” or AEETEM) as implemented by the United Nations Development Programme (UNDP), PIMS 3489 and with financing support provided by the Global Environment Facility (GEF). The Project Document (Prodoc) of 2007 provides details to remove key barriers to the commercialization of technology for die casting copper into motor rotors. AEETEM field operations commenced in August 2008, with an inception workshop conducted on December 6, 2009. Though AEETEM was designed as a 3-year project, the project expenditures of USD 250,000 were exhausted by March 31, 2012.

## 1.1 Background

### 1.1.1 Overview of the Energy Sector in India and the Impact of Copper Motor Rotors

India’s growing energy consumption leaves the country vulnerable to energy shortages. The Indian industrial & agricultural sector accounts for over 35% of country’s primary energy consumption that was 263 mTOE in 2011. The Bureau of Energy Efficiency (BEE) under the Ministry of Power has undertaken a number of energy efficiency programs designed reduce this energy consumption and reduce the country’s reliance on imported fossil fuels. One of these is a labelling program for motors under the Energy Conservation Act 2001.

At the commencement of this Project, the Bureau of Indian Standards (BIS) approved the standard IS 12615-2004 for the performance requirements and efficiency of 3-phase squirrel-cage energy efficiency induction motors. The intention of this BIS standard was to bring it more into line with international standards and focus on energy efficient motors. More recently, BIS updated this motor standard to IS 21615-2011 in an effort to further harmonize its motor standards with the global IEC 60034-30 of 2008, classifying IE1-Standard efficiency, IE2-High efficiency (EFF1), IE3-Premium efficiency levels, and IE4 super premium efficiency.

The issue, however, in 2004 and 2011 was the rate of compliance to the new standard and the ability of the motor manufacturing sector to employ a range of improvements in materials, design & manufacturing methods and quality control that collectively reduce the motor’s losses and boost its operating efficiency to the IS 12615-20 standard and the standard of 2011. In 2004, only a select group of manufacturers in India was able to produce energy efficient (EE) motors to this standard. In 2008, prior to the commencement of AEETEM, feedback from the manufacturers indicated that the sale of energy efficient motors (rated as EFF1) was approximately 2% of the total sales. The major reason cited for low sales was the higher initial cost of the EFF1 motors.

In 2006, ICA, through its local Indian affiliate ICPCI, was promoting the use of copper rotors:

- Average efficiency improvement of a motor with a copper rotor in comparison to an aluminium rotor motor is around 3 to 4%. This efficiency can be attributed to the comparative properties of the two metals: copper is a better conductor of

electricity, which results in less loss and associated heating of the copper rotor coil during operation and thus less cooling required for copper rotor motors. This would also result in doubling the service life of the motor over aluminium rotor motors;

- The size of a copper rotor motor reduces the required size of the motor resulting in a more compact machine. A smaller motor should result in cost saving and flatter efficiency curve from 50% to full load was also the gain.
- Small motors (<100 HP or 75 kW) dominate the motor market in India. These motors are used in various manufacturing sectors as well as for pumping in the agricultural sector. In the industrial sector, most of these motors are loaded for more than 3,000 hrs annually (roughly 11 hrs for 333 days each year). Hence, a transformation of the small motors market will result in significant energy savings for India.

In 2006, the major issue of copper rotor motor technologies was how to accelerate its adoption within the motor manufacturing sector in India.

### **1.1.2 SMEs and Motor Manufacturing in India**

The number of SME businesses is in the order of 26.1 million of which 7.3 million are in the manufacturing sector. Most of the SMEs in the manufacturing sector are informally managed and contribute more than 45% of India's industrial production. The GoI places a high level of importance on the development of the Indian SME manufacturing sector, notably in the context of improving India's industrial development. This is reflected in a number of government programs that enable SME clusters to access new EE&EC technologies such as:

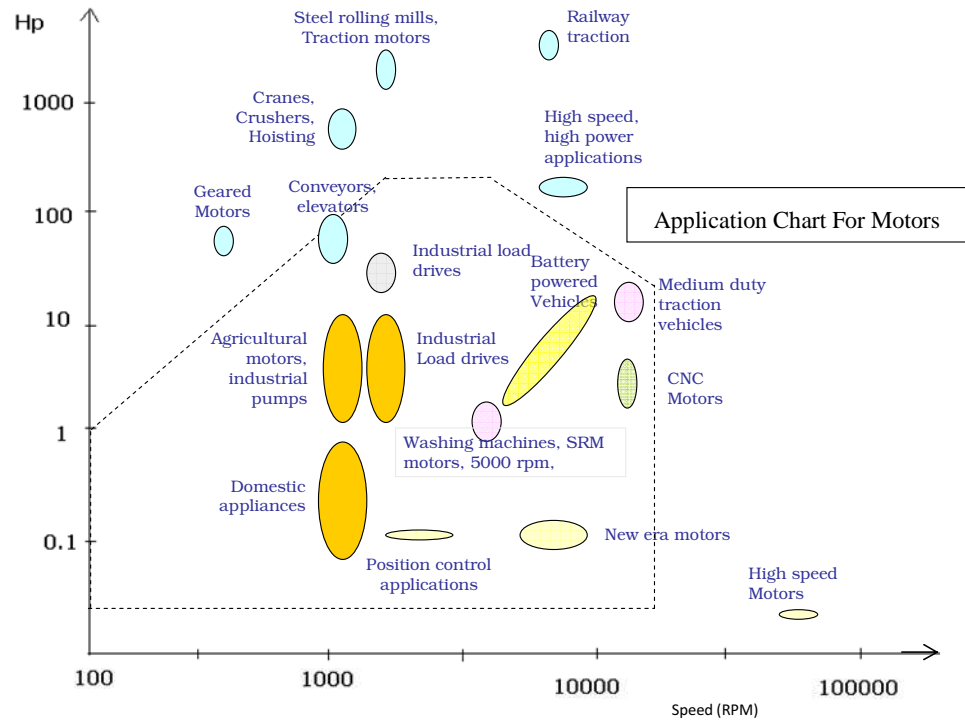
- BEE's program to increase production of energy efficient products under a financing program Energy Efficiency Financing Platform (EEFP) housed under the National Mission on Enhanced Energy Efficiency (NMEEE);
- the "Perform, Achieve & Trade" (PAT) initiative, a market based mechanism under the Ministry of Power to enhance cost effectiveness of EE improvements through tradable energy savings certificates.

There are "larger" SMEs within this manufacturing sector that manufacture small motors for the export market (mainly to Europe). However, the manufacture and sales of small motors in India are dominated by SMEs clustered in many of India's larger cities such as Surat, Ahmedabad, Coimbatore and Delhi. Most of these SMEs have small workshops where motors are made by hand. The existence of SMEs within clusters fosters learning among the SMEs and improves their manufacturing performance.

The awareness of the benefits of copper rotors among these SMEs is also excellent due to their volume of work to service the motors market (i.e. textile mills, appliance manufacturers, pump motor manufacturers, diamond cutting, etc.). However, these SMEs traditionally operate on thin margins and seek lowest cost solutions to minimize operational costs. This places SMEs servicing the small motors market in a difficult position: they need to minimize their own operational costs while improving their motors to comply with the new standards without increasing prices of their product. With a significant proportion of the small motors market classified as "informal", these SMEs cannot access any finance to improve their businesses.

While there are no official statistics on the number of motors in India, the sale of small motors (defined on this project as being between 1 and 100 hp and between 100 and 10,000 rpm speed) is estimated to be in range of 15 million annually. Predominantly, these motors have aluminium rotors. Figure 1 graphically depicts how motor applications are classified against their power output ranges and operating speeds.

**Figure 1: Motor Classifications and Applications<sup>16</sup>**



A number of SMEs are involved with the production of a fabricated rotor or the “brazed rotor” that involves the insertion of copper rods by a hand-held tool into a lamination stack; once the copper rod is tightly fit into the stack, it is brazed onto a copper end lamination stack or a brass ring at the ends of the rotor (details of a brazed rotor can be found in Appendix F). The number of brazed copper motors in the market is not known; however, its market penetration is not more than 1%. Issues related to the production of brazed rotors include:

- Production efficiency is low in comparison to die cast aluminium rotors. Copper rods need to be inserted with a hand tool into a lamination stack, swaged and silver brazed in place on to end copper lam stack or brass rings. One brazed copper rotor of 5 HP can take as long as 2 days to manufacture. Some outsource induction brazing facility to reduce cycle time. By comparison, aluminium rotors are made by pouring molten aluminium into the rotor lamination stack through a mechanized process;

<sup>16</sup> Source: NFTDC

- Lack of efficiency gains with brazed copper rotors. Rotor efficiency tests between aluminium cast, brazed and copper-die cast rotors indicates that there are no marked efficiency gains with brazed rotors<sup>17</sup>. This may quite possibly be related to the joint resistance quality of brazed joints;
- Lack of flexibility of the brazed rotor for improved design and efficiency. Brazed rotor design is usually fixed by the shape of the copper rod, which is usually circular or rectangular in cross section. As such, most SMEs would prefer not to change the cross sectional shape of the copper rod (for efficiency gains) as their extruded copper supplier may not be able to supply different shapes of copper rods;
- Use of the existing aluminium die-cast machine for copper die-casting is not possible due to the different material and melting properties of copper. This was a major barrier in 2006 to an automated process for producing copper rotors;

As of 2006, SMEs did not have the ability to produce rotors to meet the high efficiency (EFF1) standard, due to their inability to implement a range of improvements in manufacturing methods and quality control. These improvements include high-grade low-loss steel cores in the stator laminations, air gap control, improved insulation, greater copper content in the stator windings, improved resins and varnishing practices, and better temperature control in the baking/curing process and use of energy efficient bearings. These improvements are required to collectively reduce the motor's losses and boost its operating efficiency to the required IE4 standard.

### 1.1.3 Rationale for AEETEM

The primary rationale of AEETEM was to accelerate market transformation of the EFF1 motor market. In 2006, the only method of manufacturing copper rotors in India was by the slow and inefficient methods by hand to produce the brazed copper rotor; as such, these levels of production would have led to a lack of market penetration of EFF1 motors for several years.

In 2006, the ICPCI and ICA were raising awareness of motor manufacturers of India of alternative and more efficient manufacturing processes for copper rotors, namely die-casting of copper as an alternative to the brazed copper rotor. A horizontal high pressure copper die-cast machine was initially identified for use by motor manufacturers in India; the cost of this machine, however, was deemed too costly.

The Non-Ferrous Technology Development Center (NFTDC) in Hyderabad provided a proposal to ICA/ICPCI for the development of a vertical high pressure copper die-cast technology that could be used by small motor SMEs in India to produce copper motor rotors on a commercial scale. The key to NFTDCs proposal was:

- to design and create a similar die-cast machine using designs of the vertical aluminum die-cast presses in India that NFTDC claimed could be converted to copper die-cast presses;
- the cost of an indigenously developed copper die-cast machine would be far less costly than the imported horizontal press.

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<sup>17</sup> Test results from Shroffs Engineering Ltd. In Vadodara, Gujarat

In 2006, ICPCI coordinated efforts to raise funding for the development of NFTDCs vertical high pressure copper die-cast machine for producing copper motor rotors (this technology is referred to as CMR technology). The NFTDC proposal raised an outlay of USD 1,364,000 of which USD 250,000 was committed from GEF (in 2008); USD 604,000 from CFC (Common Fund for Commodities) in 2006, which covered technology development and equipment purchases; USD 300,000 from ICA (International Copper Association), which covered a number of marketing aspects; and USD 210,000 from NFTDC, which were in-kind contributions for technology development.

## 1.2 Project Goals, Objectives and Expected Results

The project development **goal** is to introduce technology for high pressure copper die casting for manufacturers of copper rotors and electric motors to achieve energy savings.

To achieve this goal, the Project was designed with a number of expected **project outcomes**:

- Outcome 1: An enabling technology center was set up and is fully functional;
- Outcome 2: Copper motor rotor (CMR) technology was assimilated and upgraded;
- Outcome 3: CMR technology was transferred and commercialized.

Section 2 will provide more detail on the achievements to date of the project's outcomes and outputs.

## 1.3 Final Evaluation

### 1.3.1 Purpose of the Evaluation

For all UNDP projects funded by GEF, a final evaluation (FE) is required after completion of a project to provide a comprehensive and systematic account of the performance of the completed project by evaluating its design, process of implementation and achievements vis-à-vis GEF project objectives and any agreed changes during project implementation. As such, the FE for this Project will serve to:

- promote accountability and transparency, and to assess and disclose levels of project accomplishments;
- synthesize lessons that may help improve the selection, design and implementation of future GEF activities;
- provide feedback on recurrent issues across the portfolio, attention needed, and on improvements regarding previously identified issues;

- contribute to the GEF Evaluation Office databases for aggregation, analysis and reporting on effectiveness of GEF operations in achieving global environmental benefits and on the quality of monitoring and evaluation across the GEF system.

This Final Evaluation was prepared to:

- ⇒ be undertaken independent of project management to ensure independent quality assurance;
- ⇒ apply UNDP norms and standards for evaluations;
- ⇒ assess achievements of outputs and outcomes, likelihood of the sustainability of outcomes; and if the project met the minimum M&E requirements;
- ⇒ report basic data of the evaluation and the project, as well as provide lessons from the Project on broader applicability.

An evaluation mission was fielded to India between the cities of New Delhi, Surat, Ahmedabad and Hyderabad between the 14<sup>th</sup> and 21<sup>st</sup> of May 2012. The Terms of Reference (ToRs) for the Final Evaluation are contained in Appendix A.

### **1.3.2 Key Issues to be Addressed**

Key issues addressed on this FE include:

- The appropriateness of the AEETEM concept and design in the context of commercializing CMR technology in India;
- Implementation of AEETEM in the context of relevance, efficiency and effectiveness of the activities;
- AEETEM impacts based on current outputs and outcomes and the likelihood of sustaining project results;
- Other competing CMR technologies in India and their impact on the CMR technology being developed at NFTDC; and
- The future role of NFTDC as an enabling technology center for CMR technology.

Outputs from this FE will provide guidance in charting future directions on increasing the market share of CMRs in the Indian electric motor market.

### **1.3.3 Evaluation Methodology and Structure of the Evaluation**

The methodology adopted for this evaluation includes:

- Review of project documentation (i.e. APRs, meeting minutes of Steering and Advisory Committees) and pertinent background information;



- Interviews with key project personnel including the Project Manager, technical advisors (domestic and international), demonstration project proponents, investors and relevant UNDP staff;
- Interview with relevant stakeholders from Government;
- Field visits to selected project sites and interviews with beneficiaries.

A full list of documents reviewed and people interviewed is given in Annex B (with the list of questions prepared for motor manufacturer and diecast processor). A detailed itinerary of the Mission is shown in Appendix C. The Evaluation Mission for the UNDP-GEF project was comprised of one international expert and one national expert.

This evaluation report is presented as follows:

- An overview of project achievements from the commencement of operations in August 2008;
- An assessment of project results based on project objectives and outcomes through relevance, effectiveness and efficiency criteria;
- Assessment of sustainability of Project outcomes;
- Assessment of the replication or catalytic effect of the Project;
- Assessment of monitoring and evaluation systems;
- Assessment of progress that affected Project outcomes and sustainability; and
- Lessons learned and recommendations.

This evaluation report is designed to meet GEF's "Guidelines for GEF Agencies in Conducting Terminal Evaluations, Evaluation Document No. 3" of 2008:

<http://www.thegef.org/gef/sites/thegef.org/files/documents/Policies-TEguidelines7-31.pdf>

The Evaluation also meets conditions set by the UNDP Document entitled "UNDP GEF – Terminal Evaluation Guideline" (<http://erc.undp.org/resources/docs/UNDP-GEF-TE-Guide.pdf>) and the UNDP Document entitled "Handbook on Planning, Monitoring and Evaluating for Development Results", 2009:

(<http://www.undp.org/evaluation/handbook/documents/english/pme-handbook.pdf>)

and the "Addendum June 2011 Evaluation":

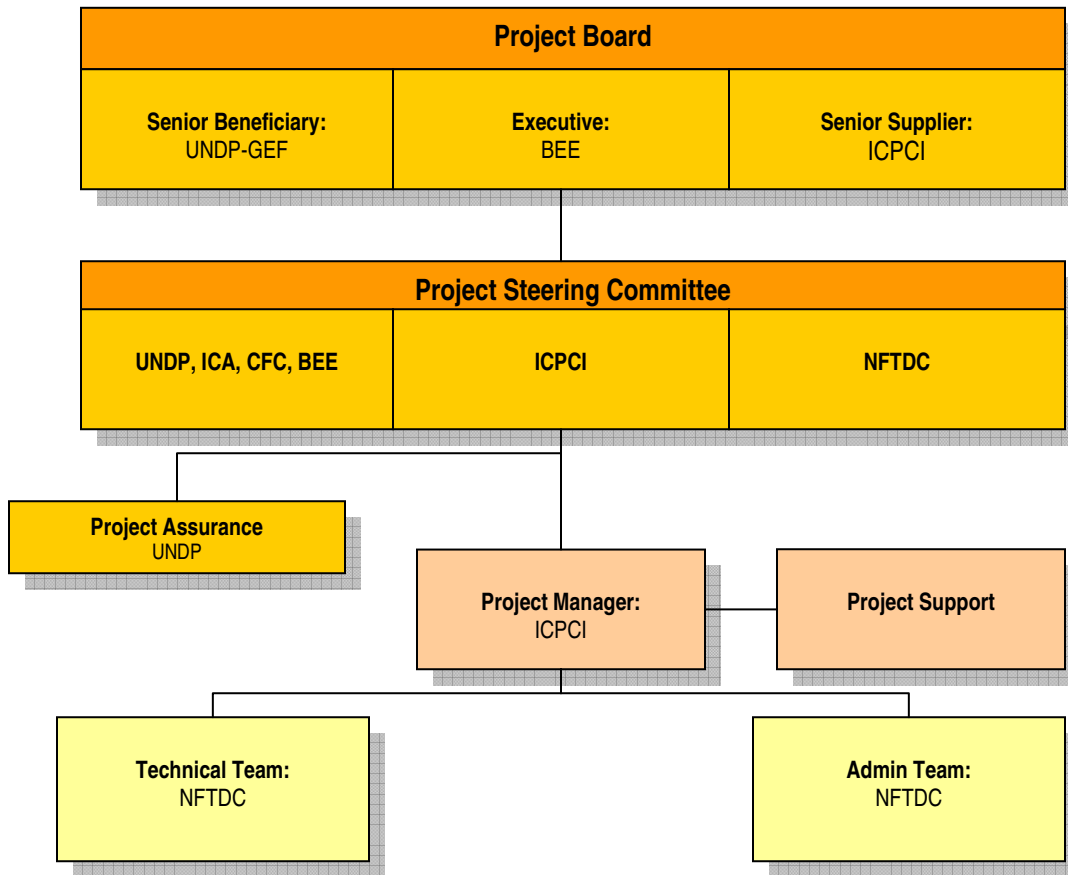
<http://www.undp.org/evaluation/documents/HandBook/addendum/Evaluation-Addendum-June-2011.pdf>

#### **1.3.4 Project Implementation Arrangements**

AEETEM was implemented by ICPCI in close cooperation with BEE. Although this is a project under NEX modality, BEE ceded project operations to ICPCI to overcome difficulties of merging UNDP-GEF funds with the Gol financial systems. As such, ICPCI was appointed as the agency with the Project Management Unit (PMU) to be guided by a Project Steering Committee (PSC). This PSC included representatives from BEE, CFC, ICPCI, NFTDC, the International Copper Study Group (ICSG) and UNDP-GEF. The Project Manager from ICPCI provided the overall direction to the project, and as the

head of the PMU, he is closely coordinating the project with the NFTDC team, and providing progress reports to UNDP India.

**Figure 2: AEETEM Project Implementation Arrangements in 2012**



## 2. ASSESSMENT OF PROJECT RESULTS

### 2.1 Overview of Project Achievements and Results

AEETEM operations commenced in August 2008 and terminated on March 31, 2012. A summary of AEETEM achievements and results follows:

- The Enabling Technology Center (ETC) successfully launched at NFTDC in August 2008. The NFTDC patented the 50 ton and 250 ton vertical die-cast presses (referred to as the VDC50 and VDC250 and collectively as “VDCs” or “CMR technology”), which was housed in a separate enclosure on the NFTDC campus, and operational as of November 2007 prior to the commencement of AEETEM. From November 2007 to May 2010, test trials for copper die-casting were conducted until there was sufficient confidence to commence pilot production;
- Since May 2010, the VDCs produced 427 copper die-cast rotors on a pilot basis for 10 external clients. This is a good indicator of the awareness and interest among motor OEMs of the potential commercial scale production of CMRs. According to ICPCI, there are another 12 OEMs wanting to have CMRs produced at the ETC;
- Engagement of OEMs with NFTDC to produce CMRs using the VDC50 press and to improve the die-cast process in collaboration with NFTDC towards a process generating consistent quality CMRs;
- Plans are being prepared for the transfer of CMR technology to industry clusters in Surat and Coimbatore. This provides further indications of the high interest in the CMR technology of NFTDC.

### 2.2 Assessment of Project Results

Assessment of AEETEM achievements and shortcomings are provided in this section against the March 2008 Project log-frame. Each outcome was evaluated against individual criterion of:

- *Relevance* – the extent to which the outcome is suited to local and national development priorities and organizational policies, including changes over time;
- *Effectiveness* – the extent to which an objective was achieved or how likely it is to be achieved;
- *Efficiency* – the extent to which results were delivered with the least costly resources possible.

The Project outcomes were rated based on the following scale:

- *Highly Satisfactory (HS)*: The project has no shortcomings in the achievement of its objectives;
- *Satisfactory (S)*: The project has minor shortcomings in the achievement of its objectives;
- *Moderately Satisfactory (MS)*: The project has moderate shortcomings in the achievement of its objectives;

- *Moderately Unsatisfactory (MU)*: The project has significant shortcomings in the achievement of its objectives;
- *Unsatisfactory (U)* The project has major shortcomings in the achievement of its objectives;
- *Highly Unsatisfactory (HU)*: The project has severe shortcomings in the achievement of its objectives.

In addition, this Evaluation also provides an assessment (wherever appropriate) on Project impacts, positive or negative, and possible long-term effects of the outcomes or outputs.

### 2.2.1 Project Goal and Objective

Project Goal: Introduce technology for high-pressure copper die-casting for manufacturers of copper cast rotor and electric motors to achieve energy savings.

#### Intended EOP Outcome:

⇒ Increase market share of high efficiency copper rotor motors through technology transfer and commercialization with supporting market development activities; market penetration rate of 3% after 3 years and 20% after 10 years

#### Actual EOP Outcome:

⇒ *Currently, high efficiency CMRs have not reached the market. Basic reasons for this are that technology transfer and commercialization of CMR technology has not been fully completed. However, the pilot production of CMRs generated a sample size of CMRs from which the die-casting process can be tweaked to ensure replicability of consistent production of quality CMRs.*

Rating:           relevance:    S  
                       effectiveness: MS  
                       efficiency:     MS  
                       overall rating: MS

According to global experience, commercialization of a new technology often spans several years. The commencement of development of CMR technology was in 2006. The first trial batches from the VDC50 press were produced in November 2007. Pilot production of CMRs from the VDC50 press commenced in May 2010. Efficiency tests conducted on the latest batch of CMRs for Shroffs Engineering in May 2012 indicated that there were still some inconsistencies in the efficiency of the rotors (where improvements in efficiencies of this CMR batch ranged from 0 to 2% from aluminium rotors); OEMs were expecting 3 to 4% improvements. Currently, NFTDC are continuing to work with Shroffs Engineering to adjust the die-casting process that will more consistently produce quality CMRs.

A GHG target of 360,000 tonnes of CO<sub>2eq</sub> was set as a cumulative GHG reduction 10 years after the start of AEETEM. Notwithstanding the NFTDC production of 427 copper motor rotors during the pilot production period, none of these rotors are producing any direct GHG estimates. The Evaluators, however, estimate that the CMR technology will be commercialized within 5 years at current levels of effort and resources and produce CMRs that will generate indirect GHG reductions. With the lack of weighted

aggregated sales information on motor sales, a number of assumptions were made to estimate GHG emission reductions:

- a grid emissions factor of 0.90 CO<sub>2</sub>/MWh for the Indian electricity grid<sup>18</sup>;
- commercialization of CMR technology in 5 years (2017) after completion of the Project;
- annual sales of 4 million rotors (representing about 25% market share) commencing in 2022, 10 years after the completion of the project;
- weighted average size of small motors being 5.0 kW (3.75 Hp);
- use of GEF method for calculating GHG emission reductions<sup>19</sup> is appropriate.

Table 1 summarizes the GHG reduction estimates (using GEF guidelines) that were generated during AEETEM (to its estimated terminal date of March 31, 2012).

**Table 1: Summary of CO<sub>2</sub> Reductions from the Project**

|   |                  |
|---|------------------|
| Direct emission reduction, t CO <sub>2</sub>  | 0                |
| <b>Total direct emission reduction, t CO<sub>2</sub></b>  | <b>0</b>         |
| Direct post-project emission reduction, t CO <sub>2</sub>   | 0                |
| <b>Total direct post-project emission reduction, t CO<sub>2</sub></b>   | <b>0</b>         |
| <b>Indirect bottom-up emission reductions, t CO<sub>2</sub></b><br>[Direct emissions delayed until 2018 when CMR technology is commercialized and then used a replication factor of 3]  | <b>1,078,920</b> |
| <b>Indirect top-down emission reduction, t CO<sub>2</sub></b><br>[Based on 20% market share (or 4 million CMRs sold) achieved 10 years after completion of project, through commercialized CMR technology in 5 years from end of project, and a GEF causality factor of 100%] | <b>3,056,940</b> |

### 2.2.2 Outcome 1: Enabling Technology Centre was set up and fully functional

#### Intended Outcome 1:

- ⇒ ETC is built and functioning
- ⇒ Physical installation of plant and equipment (within 1 year post project launch). Designing and fabricating furnace and other subassemblies including die inserts for copper die casting will be the main goal under the activity

#### Actual Outcome 1:

- ⇒ The ETC was built and functional as of August 2008 using mainly funds from CFC
- ⇒ The physical installation of the CMR technology (the VCD50 press) in its own building occurred in August 2008

Rating:            relevance:    HS  
                          effectiveness:    S  
                          efficiency:        S  
                          overall rating:    S

<sup>18</sup> Grid emission factors were provided by the Gol's Central Electricity Authority under the Ministry of Power on January 2012: [http://www.cea.nic.in/reports/planning/cdm\\_co2/user\\_guide\\_ver7.pdf](http://www.cea.nic.in/reports/planning/cdm_co2/user_guide_ver7.pdf)

<sup>19</sup> "Manual for Calculating GHG Benefits of GEF Projects: Energy Efficiency and Renewable Energy Projects, April 16, 2008 (GEF/C.33/Inf.18)"

The actual construction and assembly of the VCD50 press started in August 2006. The presses were delivered in January 2007, and the entire press and other equipment were housed in a separate building on the NFTDC campus in August 2008. Most of these activities were funded by CFC. From November 2007, NFTDC was able to run trial tests of CMRs production to perfect the die-casting process in preparation for pilot production runs. GEF funds to NFTDC were primarily used for the trial tests.

### 2.2.3 Outcome 2: CMR Technology has been assimilated and upgraded

#### Intended Outcome 2:

- ⇒ Successful results on pilot batches of cast copper rotors (at least two rotor sizes). (within two years post-project launch). Successful trials on two rotor sizes / models will lead generating at least 5 enquiries from manufacturers
- ⇒ Successful alliance formed with at least two manufacturers (within two years post project launch)

#### Actual Outcome 2:

- ⇒ The first pilot CMR batches were produced in May 2010. Since then, more than 18 rotor sizes and models have been manufactured for over 9 OEMs
- ⇒ Two alliances are planned, one with an industrial cluster and the other with a private OEM

Rating:           relevance:    S  
                       effectiveness: MS  
                       efficiency:     MS  
                       overall rating: MS

With AEETEM commencing operations in August 2008, NFTDC spent the first 22 months of the project (up to May 31, 2010) developing the processes for pilot production of copper rotors from the VDC50 press. The process engineering of the VDC50 required a significant amount of time to manufacture a number of trial rotor batches, with each batch improving the various die-casting procedures with the VDC50 press, and reducing the presence of “blow holes”<sup>20</sup> in the copper matrix.

In May 2010, Mehala Machinery (Coimbatore) and Happy Engineering (Surat) were the first OEMs to send orders for pilot copper rotors using NFTDC’s VDC process. Since May 2010, copper rotors from the VDC50 press were produced from NFTDC, though the number of rotors produced in 2012 was somewhat reduced; this is possibly due to other OEMs awaiting the results from NFTDC on their quest to consistently produce quality CMRs. There are at least four other OEMs awaiting a response from ICIPCI and NFTDC on further pilot rotor batches.

Mehala purchased a horizontal die-cast (HDC) press from Kitra Industries in Surat in 2004. Their experience with the HDC technology allowed them to produce over 6,000

<sup>20</sup> Blow holes are a reference to voids in the copper matrix. They are a result of the molten copper not entirely filling in the voids in the lamination stamping caused by the unique thermo-physical behaviour of copper, the absence of vents in a “closed slot rotor”, and the quicker cooling of copper. Detection of blow holes was made by taking one sample CMR (one with a deviant efficiency reading), and cutting through the copper core to detect voids. There are special instruments that can be used by the OEMs or NFTDC to detect blow holes without cutting through the die-cast rotor. NFTDC analyzed the variability of the copper die-cast process to find process measures to overcome their formation.

CMRs until 2011 and sold to the market. The production of CMRs from the HDC, however, was halted in 2011, due to the presence of blowholes in the rotors produced. This is attributed to manual handling of molten copper and constant injection pressure amongst other issues. Mehala initiated discussion with NFTDC to revive a technology transfer agreement that would facilitate access of the VDC50 press to them.

There are issues with regards to the pace and inconsistent quality of pilot rotor manufacture using NFTDC's VDC50 press. To understand these issues, one needs to understand the business arrangements between the OEMs and NFTDC in the production of pilot copper rotor batches:

- Step 1: The OEM supplies stampings and rotor design to NFTDC;
- Step 2: NFTDC produces copper rotors using the VDC technology and returns the copper rotors to the OEM for testing;
- Step 3: The OEM then supplies the test results back to NFTDC and discusses follow-up actions to improve rotor quality;
- Step 4: NFTDC makes adjustments to the VDC50 die-cast process to produce the OEM's unique rotor design.

The issues that influence the pace and quality production of CMRs using the VDC50 process are as follows:

- All OEM designs are different, requiring NFTDC to die-cast several unique designs with a lot of time expended in completing steps 2 to 4. This is especially true for optimizing the VDC operation for each rotor design that would provide consistent quality;
- A critical sample size of rotors is required to optimize the VDC process for a particular rotor design. Often this requires abundant materials (core packs) to ensure the process is perfected; in the case of NFTDC thus far, there have been insufficient materials to produce the required number of pilot batches;
- Feedback from the OEMs has not been timely on the first batches produced. Given that NFTDC does not have full-time personnel on the VDC process, VDC personnel are assigned to other technologies that are contained within the NFTDC compound. This results in long delays in achieving process optimization for a particular rotor design. Mehala received 100 rotors which were not usable due to porosity (depicted as wide variation of weights) NFTDC should infuse confidence in the minds of Mehala Machinery and Shroffs Engineering about the process viability.

The MTE mission, however, feels that these are controllable issues that can be simply overcome if there is improved management and full-time staff to do the required follow-up on the various transactions with all the OEMs.

#### 2.2.4 Outcome 3: Technology was transferred and commercialized

##### Intended Outcome 3:

- ⇒ Arrange visits of manufacturers representing minimum 60% of the market size
- ⇒ Signed at least two technology transfer agreements with interested manufacturers.
- ⇒ Received at least 10 letters of enquiries from end users and OEMs.
- ⇒ At least one Bank / financing agency launches a scheme to promote new high



**efficiency motors / products.****Actual Outcome 3:**

- ⇒ There were visits to a large number of OEMs. Project personnel, however, were unable to indicate if this represented over 60% of the motors market in India. Since visits of SME manufacturers to the ETC was not viable, the Project facilitated ETC visits to the clusters where they could more effectively address the manufacturers. Accordingly, 3 clusters (Surat, Delhi and Coimbatore) that have large SME motor manufacturers were covered. In addition, motor manufacturer associations such as IEEMA and AIEMM were approached to promote CMR technology to their members.
- ⇒ Two more TT agreements are planned now with the Surat cluster and Shroffs Engineering (Baroda). The TT agreements, however, have not yet been signed as the OEMs are awaiting consistent production of quality CMRs from NFTDC pilot batches
- ⇒ There have been a total of 13 letters of enquiries from OEMs on the VDC50 press for CMRs
- ⇒ No financing institutes have yet been involved with the launch of an EE motors scheme involving the VDC technology. The Surat cluster has contacted Government of Gujarat for the funds.

Rating:            relevance:    MS  
                          effectiveness: MS  
                          efficiency:    MU  
                          overall rating: MS

While the impact of AEETEM was significant in raising the interest and demand for CMRs, the evaluators noted that:

- there was considerable interest in the VDC technology to produce CMRs totalling more than 13 OEMs;
- while there is still high interest, much of the industry is awaiting the production of consistent quality CMRs which can be attained if the business arrangements between NFTDC and the OEMs were improved, and if NFTDC had control over the rotor designs; and
- to overcome the numerous CMR designs (with different stamping designs, laminations and rotor lengths), the production of CMRs would benefit from some standardization of the designs, if only to simplify the die-casting process. In addition, the rotor designs could be standardized to provide optimal efficiencies, a task that NFTDC is very capable of undertaking;
- there were few records of ICPCI's visits to OEMs and SME clusters. While the consequence of these efforts was the engagement of 10 OEMs/SMEs in pilot CMR production, the effectiveness of these visits was difficult to gauge due to the lack of documentation of the visits and follow-up efforts. This may have possibly been due to the lack of support staff within the PMU, which was basically one person from ICPCI.

### 2.2.5 Overall Evaluation of Project

The overall rating of the project results is marginally satisfactory (MS). This is based on the following outcomes:

- the enabling technology center at NFTDC is functional, and performing activities to develop the CMR process for commercialization;



- CMR technology was assimilated with a number of alliances that are being formed contingent on the technology being able to produce consistent copper rotors without blow holes;
- market demand for copper motor rotors was developed by the Project; however, the CMR technology has not yet been commercialized. Consistent quality from the pilot production of a particular CMR design requires time and a sufficient number of CMR batches; NFTDC has been undertaking pilot production for more than 9 OEMs, all of whom requested CMRs with multiple designs. This has resulted in NFTDC having a lack of time and resource materials to develop a sufficient number of CMRs that would lead to producing consistent high quality copper rotors.

Overall project ratings are provided on Table 2.

**Table 2: Assessment of Sustainability of Outcomes**

| Project Outcome  | Relevance | Efficiency | Effective-ness | Overall Rating |
|--|-----------|------------|----------------|----------------|
| <b>Outcome 1:</b> Enabling Technology Centre was set up and is fully functioning | HS        | S          | S              | S              |
| <b>Outcome 2:</b> CMR Technology was assimilated and upgraded                    | S         | MS         | MS             | MS             |
| <b>Outcome 3:</b> Technology was transferred and commercialized                  | MS        | MU         | MS             | MS             |
| <b>Monitoring and Evaluation</b>   | S         | MS         | S              | S              |
| <b>Overall Rating</b>  | S         | MS         | MS             | MS             |

### 3. SUSTAINABILITY OF PROJECT OUTCOMES

In assessing Project sustainability, we asked “how likely will the Project outcomes be sustained beyond Project termination?” Sustainability of these objectives was evaluated in the dimensions of financial resources, socio-political risks, institutional framework and governance, and environmental factors, using a simple ranking scheme:

- *Likely (L)*: very likely to continue and resources in place;
- *Moderately Likely (ML)*: model is viable, but funding or resources may not be in place;
- *Moderately Unlikely (MU)*: model is not viable or needs changing; and/or resources not in place; and
- *Unlikely (U)*: model is not viable and resources are not in place.

The evaluation for sustainability is shown in Table 3. The Table provides a rating of the project design and viability going forward, including availability of budget and resources for continuation.

*The overall Project sustainability rating is moderately likely (ML).* This rating is primarily based on:

- Strong Gol support for increasing the efficiency of electric motors made in India;
- Strong market demand created by ICPCI amongst SME rotor manufacturers who currently make copper rotors by hand which is time consuming, and unable to meet demand (through government pressure) for the sale of increased energy efficient motors, as per the new IE3 standard of the Bureau of Indian Standards (BIS) under Standard IS12615: 2011;
- The knowledge and capability of NFTDC to overcome the issue of inconsistent production quality if they had resources for full-time engineering staff and business development personnel;
- The lack of full commitment to resources to transfer technology to candidate industry clusters pending resolution of the issues on consistent quality production of CMRs;
- The paucity of resources to build capacity of NFTDC to provide the necessary technical support and sustained production of CMRs within the industry clusters.

**Table 3: Assessment of Sustainability of Outcomes**

| Actual Outcomes (as of May 2012)  | Assessment of Sustainability  | Dimensions of Sustainability  |
|---|---|---|
| <p><b>Actual Outcome 1:</b><br/>The ETC was built and functional as of August 2008 using mainly funds from CFC, and housed in its own building with the VCD50 press</p>   | <ul style="list-style-type: none"> <li>• <u>Financial Resources:</u> The ETC under NFTDC has financial resources to sustain its operations. However, they do not have sufficient financial resources given to them by the OEMs to undertake pilot production of for critical number of CMRs. This due to the fact many of these OEMs are SMEs that do not typically invest heavily (or at all) into research and development;</li> <li>• <u>Socio-Political Risks:</u> There are no social or political risks associated with the ETC as it works towards India's efforts to reduce its energy consumption and reliance on imported fossil fuels;</li> <li>• <u>Institutional Framework and Governance:</u> The ETC is managed under NFTDC, an autonomous institute (supported by Gol through the leasing of government land where ETC is located) that is financially self-sufficient. In addition, Gol set mandatory minimum efficiency performance standards (MEPS) for motors at the IE1 level and created demand pull through labelling of IE2 motors and associated promotional efforts;</li> <li>• <u>Environmental Factors:</u> The ETC was constructed to manufacture CMRs that would lead to a 4% reduction of energy consumption of small motors.</li> </ul> <p style="text-align: right;"><b>Overall Rating</b></p> | <p style="text-align: center;">ML</p> <p style="text-align: center;">L</p> <p style="text-align: center;">L</p> <p style="text-align: center;">L</p> <p style="text-align: center;"><b>ML</b></p> |
| <p><b>Actual Outcome 2:</b><br/>Since May 2010, when the first pilot CMR batches were produced, NFTDC produced more than 18 CMR designs, each of different sizes and designs for more than 9 OEMs using its patent- pending CMR technology. This has resulted in two alliances planned; one with an industrial cluster and the other with a private OEM</p> | <ul style="list-style-type: none"> <li>• <u>Financial Resources:</u> OEMs do not have sufficient financial resources to reimburse NFTDC to undertake pilot production of a sufficient number of CMR batches that will allow NFTDC to consistently produce quality CMRs and commercialize the CMR technology. This is due to the fact that many of these OEMs are SMEs that do not typically invest heavily (or at all) into research and development;</li> <li>• <u>Socio-Political Risks:</u> There are no social or political risks associated with the efforts between the ETC and OEMs as they work towards India's efforts to reduce its energy consumption and reliance on imported fossil fuels;</li> <li>• <u>Institutional Framework and Governance:</u> There are insufficient full-time personnel within NFTDC to follow-up with OEMs on the</li> </ul>  | <p style="text-align: center;">ML</p> <p style="text-align: center;">L</p> <p style="text-align: center;">ML</p>  |

**Table 3: Assessment of Sustainability of Outcomes**

| Actual Outcomes (as of May 2012)  | Assessment of Sustainability   | Dimensions of Sustainability   |
|---|--|--|
|   | <p>production of more pilot batches that will help NFTDC to deliver consistent production of quality CMRs;</p> <ul style="list-style-type: none"> <li>• <i>Environmental Factors:</i> No issues as the manufacturing of CMRs would lead to a 4% reduction of energy consumption of small motors.</li> </ul> <p style="text-align: right;"><b><i>Overall Rating</i></b></p>   | <p style="text-align: center;">L</p> <p style="text-align: center;"><b>ML</b></p>  |
| <p><b>Actual Outcome 3:</b><br/>Two technology transfer agreements are pending contingent on further pilot batches to demonstrate consistent quality production from CMR technology</p> | <ul style="list-style-type: none"> <li>• <i>Financial Resources:</i> OEMs do not have sufficient financial resources for NFTDC to undertake pilot production of a sufficient number of CMR batches to achieve quality consistency that will subsequently facilitate commercialization of the CMR technology and transfer agreements. In Surat, there are government programs available to assist the small motors industrial cluster to setup a CMR</li> <li>• <i>Socio-Political Risks:</i> There are no social and political risks. For one of the technology transfer agreements, the Gujarat government has program resources available to support a CMR technology center to assist the industrial sector to increase their competitiveness within national and global markets;</li> <li>• <i>Institutional Framework and Governance:</i> NFTDC would serve as a technology transfer agent to the various industrial clusters and OEMs wanting to host the CMR technology. They do not, however, have sufficient personnel to do the necessary follow-up to complete the technology transfer agreements;</li> <li>• <i>Environmental Factors:</i> The manufacturing of CMRs would lead to a 4% reduction of energy consumption of small motors.</li> </ul> <p style="text-align: right;"><b><i>Overall Rating</i></b></p> | <p style="text-align: center;">ML</p> <p style="text-align: center;">L</p> <p style="text-align: center;">ML</p> <p style="text-align: center;">L</p> <p style="text-align: center;"><b>ML</b></p> |
| <p><b>Overall Project Sustainability:</b></p>   |  | <p style="text-align: center;"><b>ML</b></p>   |

## 4. REPLICABILITY OR CATALYTIC ROLE

*The Project has played a catalytic role in stimulating the interest in CMR technology, a cost-effective manufacturing method that would reduce the cost of EFF1 motors, increase the market penetration of these motors and reduce energy consumption. In 2004, prior to the commencement of AEETEM, the ICA identified a technology for the manufacture of copper motor rotors, which was then discussed among industry representatives and NFTDC as to where the new technology would be hosted. With a high cost of importing a “horizontal die-cast” unit for copper motor rotors in 2005, NFTDC provided an alternative by designing a vertical die-cast process similar to the ones used for die casting aluminium rotors in India. Financing for developing this new process was initially undertaken by CFC in 2006, who provided USD 604,000 for developing and assembling the CMR vertical die-cast manufacturing unit.*

The funds available for CMR technology development, however, were only sufficient for design of the VDC50 press and the installation of appurtenant hardware. GEF funds under the AEETEM project in August 2008 were provided to ICPCI to market NFTDCs CMR technology to various OEMs throughout India, as well as to NFTDC to continue developing the die-casting process for copper motor rotors with the VDC.

By May 2010, NFTDC produced its first pilot batch of CMRs from the VDC 50 press with a steady stream of orders over a 2-year period from 9 OEMs and industry clusters. NFTDC records indicate that 427 CMRs of varying sizes and lengths were produced to date. While there was good interest in the VDC50 CMR technology, CMR technology development is now at a stage where further pilot batches are required to reach a state where there is consistent production of quality CMRs. *Replicability potential of the CMR technology is significant based on the lower production cost of CMR rotors from the VDC50 press; this potential, however, cannot be realized until the issues on consistently producing quality CMRs are resolved.*

## 5. ASSESSMENT OF MONITORING & EVALUATION SYSTEMS

### 5.1 M&E during Project Implementation

Ratings of the Project's Monitoring and Evaluation system<sup>9</sup> are as follows:

- Quality of M&E design – S;
- Quality of M&E implementation – S. The archive of PIRs, APRs, steering committee meetings and trip reports for AEETEM is extensive, and provides an excellent resource on project progress and evaluation of various project decisions.

### 5.2 Monitoring Long Term Changes

The Project monitoring resources were mainly expended towards efforts to use CMR technology for the pilot manufacture of copper rotor motors to the IE3 standard. One aspect related to monitoring long term changes assessed by the Evaluation Mission, was the compatibility of CMR technology to changing EE standards: *would the CMR technology be relevant when standards are raised to IE4?*

NFTDC believes the CMR technology can accommodate higher standards based on the technology's ability to cast any lamination patterns with the VDC50 press; the copper rods can be moulded into unique die-cast shapes that can be optimized for increased motor efficiencies. This can be easily done if NFTDC were able to design the lamination patterns for the OEMs, which can be die-cast in the VDC50 press. Moreover, the higher the motor efficiency standards, the more relevant and competitive is CMR technology.

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<sup>9</sup> HS or Highly Satisfactory: There were no shortcomings in the project M&E system;  
S or Satisfactory: There were minor shortcomings in the project M&E system,  
MS or Moderately Satisfactory: There were moderate shortcomings in the project M&E system;  
MU or Moderately Unsatisfactory: There were significant shortcomings in the project M&E system;  
U or Unsatisfactory: There were major shortcomings in the project M&E system;  
HU or Highly Unsatisfactory: The Project had no M&E system

## **6. ASSESSMENT OF PROCESSES AFFECTING PROJECT OUTCOMES AND SUSTAINABILITY**

### **6.1 Preparation and Readiness**

The AEETEM design assumed that the project resources and a 3-year implementation period were sufficient to commercialize the technology. These assumptions underestimated the time and effort required to optimize the production process of CMRs to the extent that it could be commercialized into some of the motor industry clusters.

The stakeholders were certainly ready for the project. Initially, a horizontal CMR press was promoted through the ICA in 2006 with NFTDC as hosts of the technology. When the high operational costs of the horizontal CMR press were revealed, NFTDC proposed the development of a vertical die-cast (VDC) press for copper in 2006 similar to the one used for aluminium rotor castings. With funding from CFC in 2006, NFTDC implemented this proposal for developing the VDC press (or CMR technology), commenced R&D in 2008 into the copper vertical casting process with CMR technology and applied for patent protection in late 2010.

ICPCI already had a large network of SME industrial associations and small motor manufacturers. At the commencement of AEETEM, they already made contact with a number of these associations and OEMs.

In conclusion, the primary stakeholders, ICPCI and NFTDC, were in a high state of readiness for AEETEM.

### **6.2 Country Ownership and Drivenness**

The BEE through its Energy Conservation Act of 2001 continues to strive for improvements in the energy efficiency of equipment and appliances through standards and labelling. With minimum energy performance standards (MEPS) for high efficiency motors (EFF1), being defined under BIS standard IS 12615: 2004, government pressure is being applied to increase the sales of EFF1 motors as per the new IE3 standard of the Bureau of Indian Standards (BIS) under Standard IS12615: 2011

BEE has been coordinating and supporting standards and labelling (S&L) programme for electrical motors, pumps and other motor driven systems such as air conditioners and refrigerators. BEE set up a task force to address the motor S&L area. This task force has members from BIS, manufacturers of motors (representing all sectors – small, medium and large), engineering consultancy firms, test labs, NGOs and other organizations. ICA is represented on the task force set up by BEE and has provided inputs and advice during 2003-04 in the area of motors and pumps. In summary, BEE has undertaken a proactive role in supporting this project as shown through their in-kind support in the changing of regulations to improve energy efficiency of motors.

The Gol has also contributed land to the ETC on the NFTDC campus. NFTDC has served as an excellent and appropriate host for the ETC. This provides further indicators of the drivenness of the Gol to achieve energy savings through market transformation of small motors with CMRs.

### **6.3 Stakeholder Involvement**

By the commencement of the Project in August 2008, the main stakeholders of the Project, ICPCI and NFTDC, were already engaged in activities towards commercialization of CMR technology. NFTDC was already erecting the building for the ETC and commissioning CMR technology equipment, and ICPCI was already contacting other OEMs and industry associations where motor rotor manufacturing activities are clustered. Their strong commitment towards the CMR technology and transformation of the motor market towards CMRs was evident throughout the duration of AEETEM.

Industry associations and OEMs were engaged by ICPCI through workshops and personal contacts specifically in motor manufacturing clusters in Surat (covering Surat, Ahmedabad and Rajkot sector), Delhi (covering the northern regions of India) and IEEMA (Indian Electric and Electronic Manufacturers' Association (whose membership covers a large geographical area of India). In general, workshops were poorly attended due to SMEs being generally too busy to attend such events; individual meetings with OEMs and SMEs at least guaranteed their views of CMRs were expressed. The impact of these meetings also raised OEM/SME interest of the prospect of accessing higher efficiency copper rotors to increase their ability to comply with the voluntary IE3 standards. A consequence to awareness raising efforts by ICPCI was the engagement of 10 OEMs/SMEs between August 2010 and May 2012 in the pilot production of CMRs from the VDC press.

To commercialize the CMR technology, NFTDC had arrangements with OEMs to die-cast CMRs based on OEM rotor designs and OEMs supplying the stampings. The problem with this arrangement was the absence of timely OEM feedback to NFTDC on the quality of pilot CMR batches, and an insufficient supply of stampings to NFTDC that would produce a critical mass of pilot CMRs to optimize the die-cast process. This was the primary cause of the CMR technology not being commercialized before the end of the Project.

### **6.4 Financial Planning**

AEETEM was planned as a 3-year project; as such, GEF resources of USD 250,000 was managed by ICPCI and used mainly to provide marketing support of the CMR technology to various CMR vendors and manufacturers throughout India. The evaluation team, however, is of the opinion that the USD 250,000 was certainly not sufficient to meet the objectives of the project. As such, additional funds would have been useful to strengthen pilot production of CMRs; this would have achieved an interim goal of consistent quality of CMRs that would lead to an earlier date of commercialization of the CMR technology.

### **6.5 Supervision and Backstopping by UNDP**

Supervision and backstopping efforts by UNDP India and the UNDP-GEF Regional Office in Bangkok were satisfactory. For a project of this size, there were few if any issues related to implementation of the project; the issues were mainly related to how the Project could meet its intended objectives within the Project timeframe.

### **6.6 Co-Financing and Delays**

The Project co-financing amounts were estimated to be in the order of USD 1.642 million, roughly six times the GEF allocation. Prior to the commencement of the Project, co-



financing was already committed from CFC. During the course of the Project, significant in-kind contributions were provided by ICPCI, NFTDC and BEE. Co-financing details can be found in Appendix D.

Delays in reaching AEETEM's outcome of commercialization of the CMR technology are mainly related to the business arrangements between the OEMs and NFTDC, the large number of lamination designs and stampings, and the lack of timely responses by the OEMs to optimize the die-cast process for a particular rotor design. The arrangements for pilot rotor die-casting were as follows:

- OEMs would provide to NFTDC the rotor design parameters (i.e. dimensions of end rings, core length, skew angle, if any, and quantity) and supply the laminations complete with their unique stamping design;
- NFTDC would provide the services to design the tools for die-casting, fabrication of the tools, stacking of the rotors to a desired length, die-casting the rotors, and machining the rotors for cleaning and exact dimensioning;
- NFTDC would return the rotors to the OEM for quality testing;
- OEMs would test the pilot batches which were often found to have “blow holes” that affect the efficiency of the rotors;
- The OEM would then provide this feedback to NFTDC for the casting of another pilot batch, using lessons learned from the first pilot batch.

The problems with this arrangement highlight the need for better engagement of the OEMs and SMEs in the rotor manufacture business:

- There were often delays in providing the rotor design;
- Insufficient stamping supplies to NFTDC by OEMs to produce a critical number of samples to optimize the die-casting process for a particular rotor design;
- Feedback on pilot rotor quality from OEMs was often several weeks or months<sup>10</sup>. As such, it was difficult for NFTDC with their current staffing levels to follow up with these OEMs to receive their feedback;
- All OEMs supplied different lamination designs and rotor lengths forcing NFTDC to adopt unique die-casting casting protocols for each rotor batch to minimize the incidence of blow holes;
- Many OEMs are SMEs that do not have the time and resources to visit with NFTDC and understand the development of the VDC process. If there were sufficient project resources, agreements could have been made with OEMs to have NFTDC in charge of the design and stamping supplies during the development of the VDC process for a particular stamping design. This would have accelerated NFTDC development to manufacture CMRs of consistent quality.

Delays were also experienced during the project over patent rights, filings, and the structure and fees of the technology transfer agreements (TTAs). While such delays are normal for new technologies, these were not critical delays and were not directly responsible for the current outcomes of the Project.

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<sup>10</sup> Though NFTDC has a facility to test rotor quality design, OEMs demonstrated their desire to conduct their own independent testing.

**Table 5: GEF Project Budget and Expenditures for 2008-2012 (in USD as of March 31, 2012)**

| <b>Outcome</b>  | <b>2008</b>   | <b>2009</b>    | <b>2010</b>    | <b>2011</b>    | <b>2012<br/>(up March<br/>31, 2012)<sup>11</sup></b> | <b>Total<br/>Disbursed</b> | <b>Total Planned<br/>for Project</b> | <b>Total<br/>Remaining</b> |
|---|---------------|----------------|----------------|----------------|--|----------------------------|--------------------------------------|----------------------------|
| Outcome 1: Enabling Technology Centre was set up and is fully functioning | 29,448        | 27,663         | 18,601         | 16,275         | 0  | 91,987                     | 30,000                               | 0                          |
| Outcome 2: CMR Technology was assimilated and upgraded                    | 17,441        | 17,701         | 3,879          | 12,309         | 0  | 51,330                     | 75,000                               | 0                          |
| Outcome 3: Technology was Transferred and commercialized                  | 0             | 2,992          | 20,590         | 4,111          | 0  | 27,693                     | 95,000                               | 0                          |
| Project Management, M&E   | 800           | 26,494         | 10,320         | 15,833         | 25,543   | 78,990                     | 50,000                               | 0                          |
| <b>TOTAL (actual)</b>   | <b>47,689</b> | <b>74,850</b>  | <b>53,390</b>  | <b>48,528</b>  | <b>25,543</b>  | <b>250,000</b>             | <b>250,000</b>                       | <b>0</b>                   |
| <b>TOTAL (cumulative actual)</b>  | <b>47,689</b> | <b>122,539</b> | <b>175,929</b> | <b>224,457</b> | <b>250,000</b>                                       |                            |                                      |                            |
| <b>TOTAL (planned)</b>  | <b>33,969</b> | <b>83,706</b>  | <b>84,658</b>  | <b>47,667</b>  | <b>250,000</b>                                       |                            | <b>250,000</b>                       | <b>0</b>                   |
| <b>% expended of Total Planned Disbursement</b>                           | <b>14%</b>    | <b>33%</b>     | <b>34%</b>     | <b>19%</b>     | <b>100%</b>  |                            |                                      |                            |

<sup>11</sup> Estimates only

**Table 6: Co-Financing and Leveraged Resources (in USD as of March 31, 2012)**

| Co financing (Type)   | IA own Financing (mill US\$) |        | Multi-lateral Agencies (Non-GEF) (mill US\$) |        | Bilateral Donors (mill US\$) |        | Central Government (mill US\$) |                    | Local Government (mill US\$) |        | Private Sector (mill US\$) |        | Other <sup>12</sup> (mill US\$) |        | Total Financing (mill US\$) |              | Total Disbursement (mill US\$) |              |
|-----------------------|------------------------------|--------|--|--------|------------------------------|--------|--------------------------------|--------------------|------------------------------|--------|----------------------------|--------|---------------------------------|--------|-----------------------------|--------------|--------------------------------|--------------|
|                       | Proposed                     | Actual | Proposed                                     | Actual | Proposed                     | Actual | Proposed                       | Actual             | Proposed                     | Actual | Proposed                   | Actual | Proposed                        | Actual | Proposed                    | Actual       | Proposed                       | Actual       |
| Grant                 |                              |        |  |        |                              |        | 0.210                          | 0.426              |                              |        | 0.300                      | 0.461  | 0.604                           | 0.604  | <b>1.114</b>                | <b>1.491</b> | <b>1.114</b>                   | <b>1.491</b> |
| Credits               |                              |        |  |        |                              |        |                                |                    |                              |        |                            |        |                                 |        |                             |              |                                |              |
| Loans                 |                              |        |  |        |                              |        |                                |                    |                              |        |                            |        |                                 |        |                             |              |                                |              |
| Equity                |                              |        |  |        |                              |        |                                |                    |                              |        |                            |        |                                 |        |                             |              |                                |              |
| In-kind               |                              |        |  |        |                              |        | 0                              | 0.15 <sup>13</sup> |                              |        |                            |        |                                 |        | <b>0</b>                    | <b>0.150</b> | <b>0</b>                       | <b>0.150</b> |
| Non-grant Instruments |                              |        |  |        |                              |        |                                |                    |                              |        |                            |        |                                 |        |                             |              |                                |              |
| Other Types           |                              |        |  |        |                              |        |                                |                    |                              |        |                            |        |                                 |        |                             |              |                                |              |
| <b>TOTAL</b>          |                              |        |  |        |                              |        | 0.210                          | 0.576              |                              |        | 0.300                      | 0.461  | 0.604                           | 0.604  | <b>1.114</b>                | <b>1.642</b> | <b>1.114</b>                   | <b>1.642</b> |

<sup>12</sup> Foundation contribution from CFC<sup>13</sup> BEE contributions to regulatory framework

## 7. LESSONS AND RECOMMENDATIONS

### 7.1 Lessons Learned

Lessons learned from AEETEM pertain mainly to the requirements for the successful design of a project involving commercialization of a new technology. Global experience indicates that at least 5 years are required before commercialization of many technologies in the manufacturing and environmental sectors. As such, similar projects should be planned with sufficient resources for:

- An appropriate pilot phase for a new technology. In the case of AEETEM, a “trial” casting phase was required to understand the behaviour of molten copper in the VDC and to develop the tools and procedures for casting copper rotors with minimal gas entrapment in the copper casting or the elimination of “blow holes”. The trial phase was then followed by a “pilot” casting phase where “batches” of CMRs with specific dimensions were manufactured for OEMs. Both the trial and pilot phases for the CMR technology has taken more than 3 years to achieve some understanding of the die-cast requirements and procedures that would consistently produce quality CMRs. The lesson learned from AEETEM is that careful design of the pilot phase framework is required prior to commercialization; this would include the actual business arrangements to prove the viability of the technology to be commercialized, and the time and personnel resources required to manage the commercialization aspects within a set time frame;
- Appropriate capacity building activities that involve the assimilation of new technologies with SMEs. Since SMEs usually undertake heavy workloads to stay in business, they generally do not have sufficient time and resources for attending workshops and other networking functions that would raise their awareness of new technologies and processes, and to build their capacities to utilize these technologies. This was a limiting factor on AEETEM: the lack of timely responses to pilot CMR batches did not provide NFTDC sufficient samples to demonstrate consistent production of quality CMRs to the extent that the CMR technology could be commercialized. The lesson to be learned from AEETEM is that technology assimilation, where SMEs are the target group, need to be designed with an appropriate level of SME assistance that minimizes their opportunity costs; this would include awareness raising activities located close to the SMEs (in clusters) or compensating the SME for the opportunity costs when attending these events;
- Understanding and overcoming the complexities of the supply chain in an informal sector. A lesson learned from AEETEM is that closer attention to the business arrangements between NFTDC and the SMEs would have mitigated the slow pace of progress in attaining consistent production of quality CMRs. An improved business arrangement would have included a dedicated NFTDC person who would be proactive in the management of the pilot production of CMRs, improving the promptness of feedback from the OEMs on the quality of the CMR batches, and an earlier date in which quality CMRs would be produced. Another improvement in business arrangements would have been for NFTDC to be in charge of CMR designs from OEMs that would have brought some degree of standardization to the design process.

## 7.2 Recommendations

Without further external resources, commercialization of CMR technology will likely not occur for another 5 years. As it is the stated intention of the Indian government to accelerate the use of EFF1 motors throughout India's industrial sector, further resources will be required to accelerate commercialization of the CMR technology to reach a target of 3% market penetration within 3 years from the end of the project<sup>14</sup>.

The following recommendations are made on this basis:

**Recommendation 1: Clarify NFTDC's future role in rotor manufacturing.** NFTDC's future role in this sector appears to be best suited to the development of new rotor designs and the dissemination of such designs to the OEMs:

- NFTDC should be the lead agency to develop the manufacturing procedures for die-casting new CMR designs using the VDC press. As changes to lamination patterns in the stampings hold the key to future efficiency gains in rotor designs, NFTDC's patented CMR technology has the versatility to die-cast any lamination designs that would provide maximum energy savings to a particular rotor design;
- NFTDC can disseminate information on the use of its CMR technology and carve its market niche in being one of the only entities that has a technology for the die-casting of copper rotors adapted to Indian conditions;
- NFTDC can transfer and support its CMR technology use to SME clusters or OEMs under a licensing arrangement. This arrangement would include a fee for NFTDC for technology transfer and a long-term technical support agreement to CMR technology users. The technical support agreement should include rotor design changes to meet future changes in motor standards to IE5 and beyond;
- NFTDC should offer services to design and implement retrofits for adopting existing aluminium die cast presses in the industries for casting copper rotors. This can reduce the cost of investment.

**Recommendation 2: Clarify ICPCI's future role in CMR promotion.** ICPCI's future role on the promotion of CMRs in this sector appears best suited to:

- the concentrated marketing of CMRs and NFTDC's VDC process due their mobility and network of contacts in the motor manufacturing sector;
- disseminating the benefits of the VDC process in terms of its flexibility to manufacture numerous rotors designs that will allow them to easily improve rotor designs for future generations of rotor improvements;
- facilitate technology transfers from NFTDC to the OEMs and SME clusters. Given that NFTDC is a design and research institute, ICPCI can be the agent for transfer of VDCs to the OEMs and SME clusters including the licensing arrangements, legal matters and fund transfers. This would also offload some of the business aspects of technology transfer from NFTDC who are likely inclined to focus on

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<sup>14</sup> High efficiency motors can be produced without CMR technology, albeit at a higher material cost depending on the relative prices of copper, aluminium and electrical steel. Therefore, the penetration level of high efficiency motors is dependent on other factors as well. International experience demonstrates that mandatory MEPS, fiscal incentives and innovative finance play a crucial role in creating demand pull. The recently revised Indian standards are a step in the right direction with the need for these standards to be supplemented with strong regulations and effective enforcement. Thus, both regulations and relative material prices will play critical roles in the competitiveness of CMR penetration for use in the broader industrial motors market in the future.

design and research projects, and accelerate market transformation (as opposed to NFTDC undertaking such tasks);

- facilitating linkages with a technology accreditation center and NFTDC with regards to technical developments and new rotor standards (see Recommendation 5);
- providing advance knowledge and strategic advice to OEMs and SME clusters on upcoming legislative changes by the GoI on improving EEF1 motor standards;
- monitoring transformation of motors market and the impact of EE motor sales on energy consumption and GHG emissions (see Recommendation 6).

**Recommendation 3: Strengthen human resources at NFTDC.** The specifics for human resource strengthening will entail the following aspects:

- Provide additional full-time staff at the ETC to provide the necessary follow-up on feedback from OEMs on the quality of pilot CMR batches including:
  - a full-time marketing person within NFTDC or a dedicated person from ICPCI who is employed to focus on the follow-up with OEMs on specific quality testing of pilot rotors, coordinating with OEMs on follow up actions, and providing direction to NFTDC engineers on the specific problems and mitigating actions to improve the production consistency of quality CMRs from pilot batches;
  - three process engineers to design alternative process protocols for die-casting of each copper rotor design;
- Develop a roster of high level NFTDC consultants to design and disseminate certain standards in rotor design. The consultants will be involved with:
  - Provisions of rotor designs that meet required minimum energy performance requirements and provide some standardization to the industry that is dominated by a lack of standards within an informal SME sector;
  - advising NFTDC on the adaptability of the CMR technology to future changes in motor efficiency standards, most notably to IE4 standards which the GoI may implement in 2014; and
  - advising NFTDC on its long-term role in advancing motor energy efficiency beyond IE4 standards (see Recommendation 4);
- Provide training programs to NFTDC personnel to maintain fresh approaches to new motor designs. These programs should be a link to NFTDC and assist them in disseminating the motor manufacturing sector evolving global best practices on increasing energy efficiency and conservation in motor designs.

**Recommendation 4: Strengthen the industrial clusters to improve their assimilation of CMR technology and new motor designs.** This will involve:

- Harmonizing, standardizing and optimizing rotor designs that will improve NFTDC's ability to produce consistent quality CMRs for the OEMs. NFTDC's consultants will need to develop a suite of die-casting procedures for certain rotor designs. As such, OEMs can then select certain rotor designs that NFTDC has the ability to produce on a consistent basis. Once NFTDC consistency is achieved, the CMR technology would be ready for transfer to an OEM or industry cluster;
- Having NFTDC engineers working closely with OEMs or industry clusters to design rotors within standards set by NFTDC consultants (this sentence doesn't make sense. Not sure what is trying to be said here). Standardized rotor designs done by OEMs and industry clusters will have better acceptance and will enable the industry to increase its production of better EEF1 motors;

- Increasing the strength of small motor cluster associations. Since most of the industry is comprised of SMEs, their opportunity costs to improve the quality of motor production are high. Future project assistance should provide the necessary resources for these small motor industry associations to attend workshops and technology demonstrations that will assist them in changing their methods of production towards EFF1 motors. It is noted here that the GoI have a number of programs designed to provide the capital costs for technology transfer of the CMR technology, notably in Gujarat; however, the capacity of the industry associations and the SME-OEMs is insufficient to prepare the proposals necessary to access these financial assistance packages.

**Recommendation 5: Provide technical development and standards to an equipment accreditation center for the design of small motors.** This will involve transfer of applicable standards and technical knowledge developed by NFTDC to the accreditation center to regulate the production of EFF1 motors. The strengthening of such a center will improve the industry's ability to produce EFF1 motors on a consistent basis and improve India's competitiveness with global markets for small motors.

**Recommendation 6: Build MRV capacity of ICPCI or an appropriate entity to monitor GHG reductions resulting from the market penetration of CMRs in small motors.** The development of a reliable MRV system for the market transformation of small CMR motors may attract climate funds or other concessional funding sources. ICPCI would be best positioned to undertake such a role due to their contacts with various industry actors in the small motors business sector. Building of MRV capacity will require the development of a sales database, protocols for ensuring reliable sales data and usage of the EFF1 motors, and training of personnel to enter and manage this data. This will raise the confidence of GHG reductions from market penetration of CMRs and attract climate funds.

## APPENDIX A – MISSION TERMS OF REFERENCE FOR PROJECT FINAL EVALUATION

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**Post Title:** International Consultant to conduct Terminal Evaluation (TE) as per the UNDP-GEF guidelines for the project “**Project 00047661 Achieving Reduction in GHG Emissions through Advanced Energy Efficiency Technology in Electric Motors**”

**Organization:** GEF-UNDP “**Project 00047661 Achieving Reduction in GHG Emissions through Advanced Energy Efficiency Technology in Electric Motors**”

**Supervisor:** Head/Programme Analyst of Energy and Environment Unit, UNDP, New Delhi

**Duration:** Maximum of 21 working days (over a period of 45 days)

**Duty Station:** Home based consultancy and travel to New Delhi, as part of the assignment.

**UNDP strives to have a workforce which reflects diversity and gender balance, and applies an equal opportunities approach. UNDP does not solicit or screen for information in respect of HIV or AIDS status. All selection is on merit.**

### I. Background

Chronic electricity shortages have become a common feature in India. Planners and administrators have been working overtime to do the needful in easing the energy situation in more ways than one. While enhancement of installed capacity is definitely one supply-side option, several issues need to be addressed when it comes to capacity addition such as long gestation periods, fuel availability, water availability, high capital costs, substantial running costs, environmental degradation and pollution. Against this backdrop, demand side interventions that effectively curtail energy demand seem also need to be emphasized not only because of lucrative return for investment but also for their shorter gestation periods and reduced emission levels.

One major segment on the demand side that has a major share in the overall energy consumption in industrial as well as agricultural sectors is electric motors. Most of the excessive energy consumption in these sectors is due to low voltage electric motors of sizes up to 37.5 kW. It is estimated that almost 35% of the energy consumption of India goes into electric motors. It is quite natural therefore, that this segment holds a substantial and significant potential for energy conservation.

The design of electric motors has been upgraded several times over the years in different ways to make them more efficient but the efficient motors have always been prohibitively costly leading to low sales volumes. Later, it was established that the efficiency of electric motors can be substantially improved by using copper die case rotors instead of the traditional aluminium die cast rotors. Usage of copper rotors also leads to an overall size reduction of the motors bringing its cost down further.



The process of manufacturing copper die cast rotors was difficult, time consuming and costly. However, the International Copper Association (ICA) offered a new technology for manufacturing copper die cast rotors known as CMR technology that promised to be cost effective and hence bring down the cost of efficient electric motors. This project was conceptualized for implementation under the UNDP-GEF banner with the intention of promoting adoption of CMR technology in the manufacture of electric motor rotors, leading subsequently to the adoption of efficient electric motors with embedded copper die cast rotors in industry as well as agriculture and the consequent environmental benefits thereof.

For more details on the project, please go to the following webpage:

<http://www.undp.org.in/sites/default/files/6-00057449-Copper-Project-Document.pdf>

This is a medium sized project with a total intended duration of four years. The project was under implementation from 22 August 2008 to 31 July 2011. In accordance with UNDP/GEF M&E policies and procedures, it is mandatory for all regular projects supported by the GEF to undergo a Mid-Term Review mid-way through the implementation phase and a Terminal Evaluation at the time of closing the project. Both, the Mid-Term Review and Terminal Evaluation are to be conducted by an independent party. In case of the above mentioned project, it is intended to commission a Terminal Evaluation since the implementation phase of the project has ended. The terminal evaluation is expected to assess the relevance, performance and success of the project. It could also look at early signs of potential impact and sustainability of results, including the contribution to capacity development and the achievement of global environmental goals, if any. It will also identify/document lessons learnt and provide recommendations that might improve design and implementation of other UNDP/GEF projects. ***The review team will comprise of an International and a National consultant.***

## II. Functions and key results expected:

The International Consultant will be the team leader and will be responsible for the quality of the report and timely submission. The National Consultant will provide supportive roles in terms of professional inputs, knowledge of local policies, local navigation, translation / language support, etc.

- A. The review team is expected to prepare an Evaluation Report based on the outline listed in Annex II while specifically including the following aspects:
1. Adequacy of the overall project concept, design, implementation methodology, institutional structure, timelines, budgetary allocation or any other aspect of the project design that the evaluation team may want to comment upon.
  2. Extent of progress achieved against the overall Project Objective disaggregated by each of the individual Outcomes, Outputs and Activities (including sub-activities); as against the Impact Indicators identified and listed in the project document. Extent of the incremental value added with project implementation.
  3. Performance in terms of in-time achievement of individual project activities as well as overall project in terms of adherence to planned timelines.
  4. Relevance and adequacy of mid-course changes in implementation strategy with PSC approval, if any and the consequent variations in achievements, if any.
  5. Degree of effectiveness of the Enabling Technology Centre while identifying gaps, if any with lessons learned and alternative scenarios, if any

6. Extent to which CMR technology has been upgraded and customized to the local situation. Identify gaps, if any, and provide alternative scenarios
  7. Extent of effectiveness of technology transfer and commercialization achieved as a direct consequence of the project and the extent to which the envisaged benefits (including avoidance of emissions) have been achieved
  8. Evaluate the impact of the project activities on the various government departments and ministries such as Ministry of Small & Medium Enterprises (MSME)
  9. Extent of effectiveness of awareness generation activities by way of quality of promotional packages / awareness material, number of Awareness Programmes, Trainings undertaken and level of awareness created. Quality of documentation, if any, produced under the project like quarterly newsletter, project website, brochure, etc. should also be considered
  10. Pattern, in which funds have been leveraged, budgeted, spent and accounted for in the project.
- B. The team should also focus their assessments on project impacts as listed:
- a) Perceptions on the “Situation at the end of the Project” as it seems to the review team at the terminal review stage
  - b) Nature and scale of the policy impact made by the project, if any, on relevant line departments of the Government or other policy making bodies
  - c) Extent of effectiveness of capacity building initiatives undertaken under the aegis of the project
  - d) Assessment of Greenhouse Gases Emission reduction achieved during the life of the project and an estimate of likely emission reductions possible in the future through continued adoption and spread of efficient electric motors based on high pressure die cast copper rotor technology
  - e) Appropriateness and effectiveness of the institutional arrangement deployed in the project with alternative scenarios, if any
  - f) Details of co-funding, if any, leveraged by the project and its impact on the project achievements (a “Financial Planning Co-financing” format is enclosed in Annex II for reporting);
  - g) The effectiveness of current monitoring and overseeing systems such as Project Steering Committee and suggestion on improvements if any

**Annex II** contains guidance on the GEF Project review criteria and explanation of terminology provided in the GEF Guidelines to Evaluations.

### **III. Cross Cutting Issues:**

Considering that UNDP is concerned about poverty reduction, local governance and promotion of gender equity, the team may look at these cross-cutting issues and comment if the project had any linkages and any achievement on these objectives has been through.

At its discretion, the team is free to include any other additional comments that are felt worth reporting.

### **IV. PRODUCTS EXPECTED FROM THE REVIEW:**

The total duration of the review and the finalization of report is 45 days, in which the Team Leader (IC) is expected to put in a level of effort equivalent to 21 days of professional inputs, including eight working day visits to New Delhi, Hyderabad & Surat. Subsequent to completion of the field visits, the Team Leader will submit and present, his/her preliminary

findings in the form of a presentation, to a group of select officials from UNDP, BEE (MoP), Implementing / Partnering Agencies and/or other members of the Project Executive Committee / Project Steering Committee and incorporate their comments in the draft report. Thereafter, the draft report will be submitted by the deadline set by the UNDP after sharing of the preliminary findings. This draft report will also be shared with UNDP's Regional Coordinating Unit, GEF M&E office, in addition to UNDP for comments. After incorporating the comments from all avenues, the team leader will submit the final report to UNDP, New Delhi (including an electronic copy). The length of the main report should not exceed 50 pages, in total. In no case should the formal submission of the final report take place after expiry of 45 day deadline from the start date of the assignment. Report should be submitted as (i) 5 hard copies each signed by the TR team, (ii) soft copy of the report and of all documents reviewed for the TR by the team in CD – 5 copies.

If there are discrepancies between the impressions and findings of the evaluation team and any of the stakeholders of the project, these should be explained in a separate sheet to be attached to the final report.

The Evaluation Report Outline should be structured along the following lines:

1. Executive Summary
2. Introduction
3. The project and its development context
4. Findings and Conclusions
  - 4.1 Project formulation
  - 4.2 Implementation
  - 4.3 Results
5. Completed tracking tool
6. Recommendations
7. Lessons learned
8. Annexes

#### **V. METHODOLOGY OR REVIEW APPROACH:**

The review approach will combine methods such as documentation review (desk study); interviews; and field visits. All relevant project documentation will be made available by the project management team, facilitated by UNDP. After studying the documentation the team will conduct interviews with all relevant partners including the beneficiaries. Validation of preliminary findings/reports with stakeholders will happen through circulation of initial reports for comments or other types of feedback mechanisms.

The consultants should provide details in respect of:

- Documents reviewed and brief summary of them in an annexure;
- Interviews and brief summary wherever relevant;
- Field visits and brief summary in annexure or where relevant;
- Questionnaires, if any;
- Participatory techniques and other approaches for gathering and analysis of data; and
- Participation of stakeholders and/or partners.

## VI. IMPLEMENTATION ARRANGEMENTS:

### Management arrangements:

Throughout the period of the review, the review team will liaise closely with the UNDP Country Director/ACD/Programme Analyst, the concerned agencies of the Government, any members of the international team of experts under the project and the counterpart staff assigned to the project. The team can raise or discuss any issue or topic it deems necessary to fulfill its task, the team, however, is not authorized to make any commitments to any part on behalf of UNDP/GEF or the Government.

Time-frame: As already described.

The team shall include eight days of site visits, the details of which can be worked out with the mission in due course. This visit will also include meetings with the officials of the Implementing Agency (BEE) and other stakeholders (ICPCI, NFTDC, etc.) to the project and UNDP officials.

After the initial briefing by UNDP Country Director/ACD/Programme Analyst, the review team will meet with the National Project Director, the officials of ICPCI and NFTDC and GEF Focal Point as required.

## VII. Educational Qualification & Years of Experience:

*Essential:* Graduate in engineering with a minimum of 10 years of relevant experience in industrial / academic/ policy experience in project management/ monitoring and evaluation/ energy efficiency. *Desirable:* Post graduate/doctorate in engineering/ certification in energy auditing/ management.

### Competencies:

1. Demonstrated skills and knowledge in participatory monitoring, review and evaluation processes;
2. Extensive experience in monitoring, review and evaluation of technology transfer projects, supported by major donor agencies;
3. Familiarity with GEF rules, regulations, project reviews and evaluations;
4. Proficiency in energy efficiency in small & medium sectors (SME)
5. Knowledge of energy efficiency policies/conditions in India and abroad through management and/or implementation or through consultancies in evaluation of donor funded projects.
6. Proficient in writing and communicating in English. The consultant to bring his/her own computer/laptop and related equipment.

## APPENDIX B – MISSION ITINERARY (FOR MAY 14-21, 2012)

The evaluation mission was comprised of an international consultant Mr. Roland Wong and national consultant Mr. S. Narasimhan in accordance with the objectives of the evaluation and obtained data relevant for making judgments regarding Project success and lessons learned.

| <b>May 13, 2012 (Sunday)</b>    |  |  |              |
|---------------------------------|--|--|--------------|
| <b>#</b>                        | <b>Activity</b>  | <b>Stakeholder involved</b>                      | <b>Place</b> |
|                                 | Arrival of Mr. Roland Wong / S.Narasimhan  |  | New Delhi    |
| <b>May 14, 2012 (Monday)</b>    |  |  |              |
| 1                               | Briefing with Dr. S.N. Srinivas and Ms. Chitra Narayanswamy, UNDP                              | UNDP India                                       | New Delhi    |
| 2                               | Briefing with Dr. Sandeep Garg and Mr. S.P. Garnaik, BEE                                       | Government of India, Bureau of Energy Efficiency | New Delhi    |
| <b>May 15, 2012 (Tuesday)</b>   |  |  |              |
|                                 | Travel to Surat  |  |              |
| 3                               | Meeting with Happy Engineering and the Surat Engineering Vikas Association                     | SME OEMs   | Surat        |
|                                 | Travel to Ahmedabad  |  |              |
| <b>May 16, 2012 (Wednesday)</b> |  |  |              |
| 4                               | Visit with Anuj Patel, National Electrical Industry, Ahmedabad                                 | SME OEMs   | Ahmedabad    |
|                                 | Travel to Vadodara   |  |              |
| 5                               | Meeting with Mr. Ramesh Shastry and Mr. Shailesh Shah of Shroffs Engineering Limited           | SME OEMs   | Vadodara     |
|                                 | Travel to Ahmedabad  |  |              |
| <b>May 17, 2012 (Thursday)</b>  |  |  |              |
|                                 | Travel to Hyderabad  |  |              |
| 6                               | Meeting with Dr. K. Balasubramanian and Mr. D. Lokeswara Rao, NFTDC and Mr. Milind Raje, ICPCI | NFTDC, ICPCI                                     | Hyderabad    |

| <i>May 18, 2012 (Friday)</i>   |  |                    |           |
|--------------------------------|--|--------------------|-----------|
| 7                              | Meeting with Dr. K. Balasubramanian and Mr. D. Lokeswara Rao, NFTDC and Mr. Milind Raje, ICPCI | NFTDC, ICPCI       | Hyderabad |
| <i>May 19, 2012 (Saturday)</i> |  |                    |           |
| 8                              | Meeting with Dr. K. Balasubramanian and Mr. D. Lokeswara Rao, NFTDC and Mr. Milind Raje, ICPCI | NFTDC, ICPCI       | Hyderabad |
| <i>May 20, 2012 (Sunday)</i>   |  |                    |           |
|                                | Preparation of the report  |                    | Hyderabad |
| <i>May 21, 2012 (Monday)</i>   |  |                    |           |
| 9                              | Mission de-briefing meeting at NFTDC   | UNDP, NFTDC, ICPCI | Hyderabad |
| 10                             | Departure of Roland Wong from India  |                    |           |

Total number of meetings conducted: **11**

## **APPENDIX C – LIST OF PERSONS INTERVIEWED AND DOCUMENTS REVIEWED**

This is a listing of persons contacted in India (unless otherwise noted) during the Final Evaluation Period only. The Evaluators regret any omissions to this list.

- 1) Dr. S.N. Srinivas, Programme Officer (Energy and Environment), UNDP India;
- 2) Ms. Chitra Narayanaswamy, Programme Associate (Energy and Environment), UNDP India;
- 3) Dr. Sandeep Garg, Energy Economist, BEE, MoP, Government of India;
- 4) Mr. S.P. Garnaik, Energy Economist, BEE, MoP, Government of India;
- 5) Mr. Milind Raje, Director Energy Solutions, ICPCI;
- 6) Mr. Sanjeev Ranjan, CEO, ICPCI;
- 7) Dr. K. Balasubramanian, Director, NFTDC;
- 8) Mr. D. Lokeswara, Senior Manager (Projects), NFTDC;
- 9) Mr. Manank Dalal, Honorable Secretary, Surat Engineering Vikas Association, Surat;
- 10) Mr. Pankaj Trivedi, Proprietor, Hydro-Pneumatic Techniks, Surat;
- 11) Mr. Kirti Waghel, Sumeet Engineering, Surat;
- 12) Mr. Badrubbhai Saiyad, Nelson Electric Works, Surat;
- 13) Mr Himamshu Parvadia, Shree Ram Electricals, Surat
- 14) Mr Manoj Kansara, R G Mechanic works, Surat
- 15) Mr. Anuj Patel, National Electric Industry, Ahmedabad;
- 16) Mr. Ramesh Shastry, Vice President, Shroffs Engineering Ltd.;
- 17) Mr. Shailesh Shah, Deputy General Manager, Shroffs Engineering Ltd.
- 18) Mr Mukundavalsalan, CEO, Mehala machines india ltd, Coimbatore
- 19) Mr Subramaniam, CMD, Mehala machines india ltd, Coimbatore
- 20) Mr Shaktivel, AGM, Mehala machines india ltd , Coimbatore

**Documents reviewed for this evaluation (all from UNDP unless otherwise noted) includes:**

1. UNDP-GEF “Achieving Reduction in GHG Emissions Through Advanced Energy Efficient Technology in Electric Motors”, CEO Endorsement Document, March 2008;
2. UNDP-GEF “Achieving Reduction in GHG Emissions Through Advanced Energy Efficient Technology in Electric Motors”, Project Document, August 2008;
3. Project APRs and PIRs from 2010 and 2010;
4. Project QPRs from 2008 to 2012;
5. Combined Delivery Reports for 2009, 2010 and 2011;
6. PSC Meeting Notes from November 2008 to April 2011;
7. ICA Project Completion report, May 31, 2012;
8. Various UNDP Mission Summary Reports (2011 and 2012);
9. NFTDC CMR Project, “Test Procedure Manual”, May 2012;
10. NFTDC CMR Report, “Documentation on Die-Casting System”, May 2012;
11. NFTDC CMR Project, “Log of Experiments and Trials Performed at the ETC”, May 2012;
12. Undated NFTDC “Rotor Testing Report”;
13. Surat Engineering Professional’s Association, “Cluster Development for Textile Machinery and General Engineering Parts – Diagnostic Study”.



## APPENDIX D – REQUIRED PROJECT IDENTIFICATION AND FINANCIAL DATA

### I. Project Identification

**GEF Project ID:**

**GEF Agency Project ID:**

**Countries:** India

**Project Title:** Advancing Energy Efficiency Technologies for Electric Motors (AEETEM)

**GEF Agency (or Agencies):** UNDP

### II. Dates

| Milestone                      | Expected date | Actual date    |
|--------------------------------|---------------|----------------|
| CEO endorsement/approval       |               |                |
| Agency approval date           |               |                |
| Implementation start           | May 2008      | August 2008    |
| Midterm evaluation             | February 2010 | Not done       |
| Project completion             | July 2011     | March 31, 2012 |
| Terminal evaluation completion | June 2011     | July 31, 2012  |
| Project closing                | July 2011     | July 31, 2012  |

### III. Project Framework

| Project component  | Activity type <sup>27</sup> | GEF financing (in \$)  |                | Co-financing (in \$) |                  |
|--|-----------------------------|------------------------|----------------|----------------------|------------------|
|  |                             | Approved <sup>28</sup> | Actual         | Promised             | Actual           |
| 1. Enabling Technology Centre has been set up and is fully functioning | TA                          | 30,000                 | 91,987         | 660,100              | 1,062,701        |
| 2. CMR Technology has been assimilated and upgraded                    | TA                          | 75,000                 | 51,330         | 283,700              | 302,088          |
| 3. Technology has been Transferred & commercialized                    | TA                          | 95,000                 | 27,693         | 105,200              | 227,282          |
| Project management   | TA                          | 50,000                 | 78,990         | 65,000               | 50,000           |
| PDF-A  | TA                          | -                      | -              | -                    | -                |
| <b>Total</b>   |                             | <b>250,000</b>         | <b>250,000</b> | <b>1,114,000</b>     | <b>1,642,071</b> |

<sup>27</sup> Inv= Investment, TA= technical assistance

<sup>28</sup> Promised co financing refers to the amount indicated at the point of CEO endorsement/approval

#### IV. Co-Financing

| Sources of Co-financing    | Type    | Project preparation |          | Project implementation |                  | Total            |                  |
|----------------------------|---------|---------------------|----------|------------------------|------------------|------------------|------------------|
|                            |         | Expected            | Actual   | Expected <sup>29</sup> | Actual           | Expected         | Actual           |
| Host gov't contribution    | In Kind | 0                   | 0        | 0                      | 150,000          | 0                | 150,000          |
|                            | Cash    | 0                   | 0        | 210,000                | 426,456          | 210,000          | 426,456          |
| GEF Agency (ies)           | Cash    | 0                   | 0        | 0                      | 0                | 0                | 0                |
| Bilateral aid agency (ies) | Cash    | 0                   | 0        | 0                      | 0                | 0                | 0                |
| Multilateral agency (ies)  | In Kind | 0                   | 0        | 0                      | 0                | 0                | 0                |
|                            | Cash    | 0                   | 0        | 0                      | 0                | 0                | 0                |
| Private sector             | Cash    | 0                   | 0        | 300,000                | 461,271          | 300,000          | 461,271          |
| NGO                        | Cash    | 0                   | 0        | 0                      | 0                | 0                | 0                |
| Other                      | Cash    | 0                   | 0        | 604,000                | 604,345          | 604,000          | 604,345          |
| <b>Total Co-financing</b>  |         | <b>0</b>            | <b>0</b> | <b>1,114,000</b>       | <b>1,642,072</b> | <b>1,114,000</b> | <b>1,642,072</b> |

<sup>29</sup> Expected amounts are those submitted by the GEF Agencies in the original project appraisal document.

## APPENDIX E – ORIGINAL DECEMBER 2007 PROJECT FRAMEWORK DESIGN

| Project Strategy   | Objectively verifiable indicators  |  |   |  |  |
|--|--|--|---|--|--|
| Goal   | Reduce GHG emissions associated with the electric motor industry.  |  |   |  |  |
|  | Indicator  | Baseline   | Target  | Sources of verification  | Risks and assumptions  |
| <b>Objective:</b> Introduce technology for high pressure copper die casting for manufacturers of copper cast rotor and electric motors to achieve energy savings | Quantity of high efficiency copper rotor motors sold per year by manufacturers in India and from other South Asian countries. (3 years form the commencement of project) | Number of motors sold per annum in India, percentage share of conventional energy efficiency motors.                                 | Increase market share of high efficiency copper rotor motors through technology transfer and commercialization with supporting market development activities; market penetration rate of 3% after 3 years and 20% after 10 years  | Market data, information supplied by motor manufacturers (ones which acquired and commercialized the copper rotor motors technology from CoE). | <ul style="list-style-type: none"> <li>- Technology risk</li> <li>- Market risk</li> <li>- Implementation risk (Please refer note #1)</li> </ul> Assumptions: <ul style="list-style-type: none"> <li>- Policy environment encouraging energy efficiency</li> <li>- Business environment conducive to setting up additional capacity for copper rotor manufacturing</li> </ul>                              |
| <b>Outcome 1:</b> Enabling Technology Centre has been set up and is fully functioning  | ETC is built and functioning<br><br>Physical installation of plant and equipments. (within 1 year post project launch)   | No ETC<br><br>Principal equipment is vertical die-casting machine and associated dies / die inserts.                                 | Physical commencement of operations of the proposed ETC. (Within 1 year post project launch)<br><br>Designing and fabricating furnace and other subassemblies including die inserts for copper die casting will be the main goal under the activity. Successful fabrication will lead to cost effective commercialization of the process. | Periodic (quarterly) progress reports from ICA/ ICPCI<br><br>Periodic progress reports by ICA and ETC.   | Risk: Delay in construction of bay.<br>Assumption: Construction would be undertaken by reputed local construction firm. Hence no major risk in completion.<br>Technology risk.<br>Assumption: NFTDC has good track record in developing and fabricating large number of equipments including specialized furnaces for oxygen free copper. Fabricating high quality equipment will not pose any challenges. |
| <b>Outcome 2:</b> CMR Technology has been assimilated and upgraded   | Successful results on pilot batches of cast copper rotors (at least two rotor sizes). (within two years post project launch)   | In the absence of the high pressure copper die casting technology there is no commercial manufacture of copper cast rotors in India. | Successful trials on two rotor sizes / models will lead generating at least 5 enquiries from manufacturers  | Logs of experiments and trials performed at ETC. Letters of enquiries from manufacturers.  | Technological risks<br>Assumptions: The technology has been proven in USA and in Europe on lab level. Technical experts will be providing support. Considering track record of   |

|  |  |   |  |  |   |
|--|--|---|--|--|---|
|  | Successful alliance formed with at least two manufacturers (within two years post project launch)  | Today manufactures use aluminium die-cast rotors  | Approximate size of manufacturing capacity expected to be installed for copper rotor manufacture.  | Alliance contracts entered into between manufacturers and ETC.   | NFTDC, there is minimum risk associated with trials. Risk perceived by some manufacturers. Assumption: ICA has already received expressions of interest from some of the leading motor manufacturers to participate in the proposed project. There is considerable interest in technology acquisition.  |
| <b>Outcome 3:</b> Technology has been Transferred & commercialized | <p>Arrange visits of motor manufacturers to ETC &amp; demonstrate technical feasibility for copper die-casting</p> <p>Signed technology transfer agreements (at least with two manufacturers) (Within 3 years post project launch)</p> <p>At least 10 letters of enquiries from end users and OEMs (Within 3 years post project launch) as result of market development programs and awareness building exercise.</p> <p>At least one Bank / financing agency launches a scheme to promote new high efficiency motors / products. (Within 3 years post project launch)</p> | <p>No knowledge of copper die-casting with Indian motor manufacturers</p> <p>Partner organizations indicated willingness to work jointly.</p> <p>At present there is no awareness about cast copper rotors</p> <p>Conventional financing arrangements will serve to certain extent.</p> | <p>Arrange visits of manufacturers representing min 60% of the market size</p> <p>Signed at least two technology transfer agreements with interested manufacturers.</p> <p>Received at least 10 letters of enquiries from end used and OEMs.</p> <p>Specific financing scheme with view to encouraging use of high efficiency motors with copper cast rotors by at least one bank of financing agency.</p> | <p>Visit Reports</p> <p>Reports of technology market development workshops</p> <p>Letters of enquiries received by motor manufacturers.</p> <p>Actual launch of schemes by financing agencies.</p> | <p>Risk: Higher level of incremental investment for commercialization. Assumption: Trials on vertical press are expected to reduce production cycle time. Technology risk and perceived risk by manufacturers. Assumption: Cost-benefit results would enable convincing manufacturers to sign for tech transfer</p> <p>Market risks<br/>The cost premium of the high efficiency motors perceived high. Assumption: Total input cost of the materials (for copper rotor will be lower (as compared with aluminium rotor of same rating) resulting into better economics. Financing risks perceived by banks and institutions. Assumption: Cost effective efficient technology promotion with conducting efficiency supporting policies will encourage banks to promote better schemes.</p> |

## APPENDIX F – NOTES ON THE BRAZED ROTOR

A brazed rotor (also referred to as a fabricated rotor) refers to the joining process of the laminated stampings that are metal plates with holes in them for aluminium or copper rods. The copper rods that are inserted into the holes of the stampings are joined to end rings by processes that involve punching of the end rings, application of heat to the rods and rings, and resistance welding that is done through special purpose machines, fixtures and precisely machined parts. The silver brazing process commonly used by SMEs is done through manual labor and with skilled personnel to handle torch brazing.

The productivity of the brazed rotor process is very low. Surface preparation is required and appropriate fluxing is required to develop resistance for any free joints in the rotor. This process is normally outsourced.

The reason induction brazing cannot be used to automate production of brazed copper rotors, is due to the fact that skewing is not possible (the stator had to be skewed). Furthermore, the rotor slot shape had to be rectangular or circular as copper bars can only be purchased in those shapes. Optimisation cannot be achieved through induction brazing. Notwithstanding the copper rotor's improved performance (i.e. improved efficiency, increased power to weight ratio, increased torque per ampere ratio, lesser operating temperature, reduced slip, reduced frame size for the same power compared to aluminium rotor, and improved power factor), there is not much interest in induction brazing by CME motor manufacturers.