Development of Super Efficient Equipment Programme (SEEP) for Fans:

Concept, Programme Design, and Implementation Framework

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Prayas Energy Group

[1]Girish Sant passed away unexpectedly in February 2012. He played a key role in the conceptualisation, development and implementation of SEEP.

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About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non-governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. The Prayas Energy Group works on theoretical, conceptual regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas Energy Group has contributed in the energy sector policy development as part of several official committees constituted by Ministries and Planning Commission. Prayas is registered as SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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List of Abbreviations

BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BLDC	Brush-Less Direct Current
CCE	Cost of Conserved Energy
CERC	Central Electricity Regulatory Commission
CISPR	Comite International Special des Perturbations Radioelectriques
CLASP	Collaborative Labelling and Appliance Standards Program
CMM	Cubic Metres per Minute
DSM	Demand Side Management
ECEEE	European Council for an Energy Efficient Economy
EMI	Electro-Magnetic Interference
EMV	Evaluation, Monitoring and Verification
FMIA	Fund Management and Implementation Agency
IPEEC	International Partnership for Energy Efficiency Cooperation
LBNL	Lawrence Berkeley National Laboratory
MA	Monitoring Agency
NPC	National Productivity Council
PF	Power Factor
RAP	Regulatory Assistance Project
RFP	Request For Proposal
S&L	Standards and Labelling
SEA	Super Efficient Appliance
SEEP	Super Efficient Equipment Programme
SERC	State Electricity Regulatory Commission
SSEF	Shakti Sustainable Energy Foundation
THD	Total Harmonic Distortion

1. Introduction

The Bureau of Energy Efficiency (BEE) will soon launch its first programme for super-efficient (SE) fans as part of the recently approved Super Efficient Equipment Programme (SEEP). SEEP is designed to facilitate a rapid transformation of the market for household appliances to super-efficient models which are about as efficient as the most efficient models available worldwide. Prayas has assisted BEE in the development of SEEP from its conception. It has contributed to the design of the programme as well as to the framework for its implementation.

Now, as SEEP begins to be implemented, many people who may not be familiar with the programme will get involved in its implementation. The primary objective of this document is to provide an overview of the programme for these people. Additionally, the document archives our experience in the development of SEEP, particularly regarding issues that came up, decisions that were made, and the rationale behind them. In addition to its relevance for SEEP for fans, this experience will also provide lessons for SEEP for other appliances, and similar programmes.

Prayas has been working towards energy efficiency since its inception. In recent times, our work has focused on the rapid and large-scale implementation of energy efficiency. As part of this effort, we initially identified high priority areas which have the largest savings potential, and explored strategic actions for each such area which would facilitate rapid scaling-up in the Indian policy and implementation environment. As an example, Prayas suggested national programmes to give upstream incentives to manufacturers to facilitate the rapid transformation of the market towards super-efficient appliances. SEEP emerged from the concept behind such national programmes.

This paper narrates the development of SEEP, including the stages of conceptualisation, design, and planning for its implementation. Section 2 of the paper explains the rationale for SEEP, and for selecting fans for its first programme. Section 3 outlines SEEP's basic features. Section 4 elaborates on the design of the programme and the process of its development. Section 5 describes the role of collaborators and partners. While section 6 discusses the implementation framework for SEEP, section 7 lists the lessons learnt during the development of the programme. Section 8 discusses potential pitfalls and challenges, and section 9 concludes the paper.

2. Background and Rationale

India's high economic growth has resulted in booming sales of electrical appliances in both residential and commercial sectors, placing a tremendous burden on the resource-strained power sector. A limited supply of the resources required for power generation including land, fuel, and water and rising concerns about its human and environmental impacts pose serious challenges to building new power plants. Energy efficiency measures reduce the need for additional capacity, and promotion of highly energy-efficient models of long-lasting electrical appliances is one such measure that offers long-term savings of electricity.

BEE established a standards and labelling (S&L) programme for different electrical appliances in 2006. While the programme is mandatory for some appliances, it is voluntary for others. Every model is rated for its energy efficiency with a certain number of stars, such that a model with a 5-star rating is considered the most energy-efficient. Appliances for which the programme is mandatory must earn at least one star before they can be marketed. While there has been an encouraging shift to more efficient models in the case of some appliances, for many others, new buyers still buy inefficient but less expensive models. For example, in 2009-10, almost 90% of purchases of labelled frost-free refrigerators fell in the 4 or 5 star category (NPC, 2010). However, in the case of room air conditioners (ACs), only 14% of products purchased were rated with 4 or 5 stars, while 55% were rated with 1 or 2 stars. Moreover, for appliances for which labelling is not yet mandatory, a large fraction of purchases are of unlabelled models. In addition to the slow adoption of more efficient rated products, the energy consumption thresholds for labelled products have not been made more stringent as rapidly as had been expected. One reason for this is the resistance from manufacturers, particularly in the unorganised sector, who may find it difficult to improve manufacturing technologies.

In some states, utilities have initiated programmes, mostly for subsidised sales of CFLs, T-5 tube-lights, ACs and fans, where the utility recovers the cost of the programme through the annual revenue requirements which form the basis of tariffs. However, these pilot programmes have only been deployed on a small scale. Overall, the development of utility-administered Demand Side Management (DSM) programmes in India has been sluggish, and their impact on the shift to efficient appliances small. Some reasons for the slow pace of development are: (1) Utilities and regulatory commissions lack expertise in DSM; (2) The attention of utilities is diverted to other issues such as electricity shortages and high distribution losses; and (3) Utilities are reluctant to propose and design programmes on their own.

Crucially, there is still a very large difference in the energy consumption between the best technology available in international markets, and current 5 Star level appliances in India. As most Indian consumers are very conscious of the initial cost of an appliance, highly efficient but more expensive models are not sold in the Indian market. Table 1 lists the differences in efficiency levels between current 5 star models in India, and super-efficient models available commercially in international markets, for the four appliances that are responsible for about half the consumption in Indian households: room air conditioners, frost-free refrigerators, televisions, and ceiling fans.

The gap between the average efficiency of appliances sold in the Indian market and the most efficient commercially available appliances worldwide must be quickly narrowed to capture as much as possible of the existing large energy saving potential. At the same time, any approach to narrow the gap must address the challenges posed by the limitations of expertise, human and financial resources in utilities and regulatory commissions. SEEP provides a promising approach with a focus on market transformation through incentives to manufacturers to develop and sell super-efficient appliances (SEAs). A rapid market transformation to super-efficient variants of only four appliances – room air conditioners, refrigerators, television sets, and ceiling fans – has a potential of saving 60 million units of electricity in 2020, which is about three times the potential savings from an aggressive standards and labelling program. This translates to avoiding a peak capacity addition of 20,000 MW (Chunekar et al., 2011).

Table 1: Comparison of Performance of 5-Star Appliances and Super-Efficient Appliances (SEA)

Appliance	Unit	5 Star level in India (2010)	SEA level (2010)	Decrease in Unit Energy Consumption (%)	Basis for SEA level[2]
Room Air Conditioners	EER[3]	3.1	4.9	36	The most efficient grade 1 AC (1.5T) in China (Source: Top 10 China, 2010)
Frost-Free Refrigerators	kWh/yr	411	128	69	The most efficient grade 1 215 litre FF refrigerator consumption in China (Source: Top 10 China, 2010)
Televisions	W	62	36	42	A 32" LCD model in the US with LED backlighiting and auto brightness control consumes 36 W. (Source: Top 10 US, 2010)
Ceiling Fans	W	51	35	32	Use of brushless DC (BLDC) motor

Source: Chunekar et al., 2011

3. Basics of SEEP

3.1. Key Features

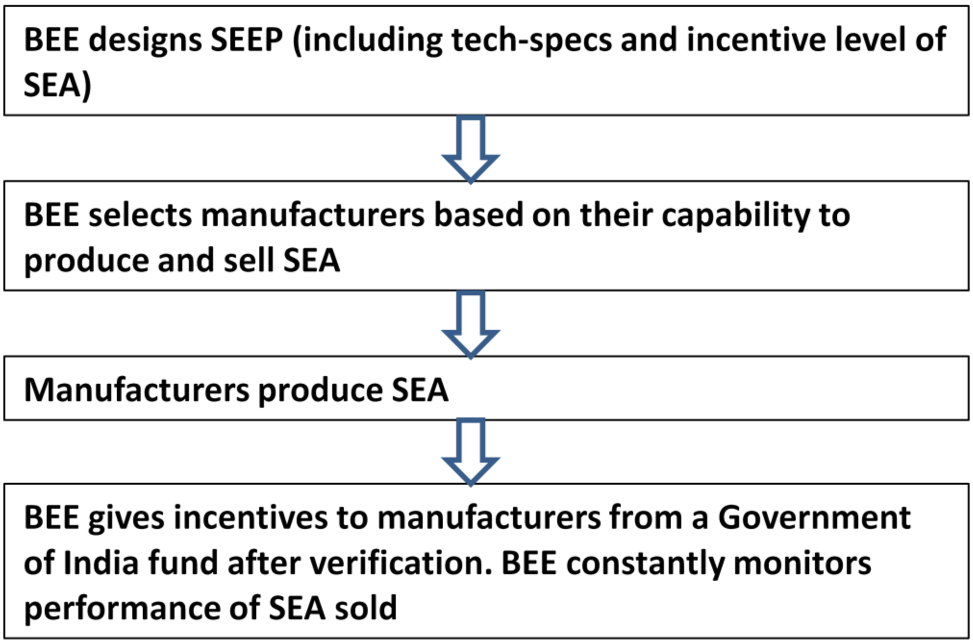
The basic process of SEEP is outlined in figure 1. This basic structure of the programme brings out some key features of the program. The first key feature of SEEP is that unlike a utility DSM programme which is designed and implemented by each utility, a SEEP programme will be designed and implemented to a large extent by BEE, which will reduce the burden on utilities and state regulators considerably, and bypass many of the difficulties in utility-administered programmes. If each State Electricity Regulatory Commission (SERC) decides to initiate DSM in its respective state independently, its regulatory burden for developing regulations, issuing orders, assessing DSM programme proposals, approving Monitoring and Evaluation (M&E) reports, and reviewing them would be substantial, particularly because these tasks will have to be performed repeatedly. However, if BEE designs the DSM programmes, implements them, and arranges for M&E, it will substantially reduce the burden on utilities and regulators.

The second key feature of SEEP is the provision of incentives to manufacturers for selling SEAs. The required incentive under SEEP is expected to be considerably lower compared to an equivalent utility-administered programme for two reasons. First, giving upstream incentives avoids wholesale and retail mark-ups and taxes. Second, one entity negotiating on behalf of all utilities in India would have much greater bargaining power while negotiating with manufacturers owing to the larger market size at stake compared with each utility attempting to negotiate with manufacturers

[2]There may be some variation across countries in testing protocols to compute efficiency for ACs and refrigerators. However the magnitude of variation is small.
[3]EER: Energy Efficiency Ratio

separately. In addition, manufacturers can take advantage of the greater economies-of-scale from selling appliances to a national market, as compared to selling in each utility service territory and meeting the individual DSM programme specifications. Greater bargaining power and larger economies-of-scale are likely to lead to lower programme costs for a national-scale programme than those for several utility-scale programmes.

Figure 1: Basic Processes of SEEP



Upstream incentives through SEEP thus serve two functions: (1) they provide incentives to manufacturers to develop and sell SEAs that they would not otherwise sell, thus bringing about a market transformation towards much more efficient products; and (2) they lower the monetary price for customers, thus serving the same purpose as customer rebates but at a lower cost to the subsidising agency.

3.2. Benefits

Apart from considerably reducing the burden on state regulators and utilities, SEEP's key features result in some significant benefits:

3.2.1 Reduced Transaction Costs and Greater Effectiveness

Figure 2 is a graphic representation originally developed by Ranjit Bharvirkar of Itron Consulting for programmes like SEEP. Two important features of any DSM programme are: (1) the geographic scope of the programme and (2) the point of intervention for providing incentives. The horizontal axis in figure 2 shows the geographical scope of the programme which increases from utility level to national level. The vertical axis shows the point of intervention for providing incentives which goes upstream from customer to manufacturer. A utility administered programme would lie in the lower left corner of this graph, because the scope is limited to the utility and the incentive is provided to the customer usually in the form of a rebate. On the other hand, SEEP lies in the upper right hand corner, because the scope is at the national level, and the incentive is provided upstream to the manufacturers.

In Figure 2, the number of transactions decreases as we expand the geographical scope of the programme from the utility-scale to the national-scale. The number of negotiations between each utility and various manufacturers would be substantially larger than the number of transactions between just one entity, BEE and various manufacturers. Similarly, the number of transactions decreases as the point of energy efficiency programme intervention moves from customer to manufacturer. Customer decision-making with respect to appliance purchases is driven by various factors such as the cost of the appliance, its utility value, usability, aesthetics (e.g. size, colour, form, etc.), brand value, and potential future energy savings. In contrast, the manufacturer's decision-making process is entirely driven by only one factor, profit. Clearly, influencing millions of customers with varying decision-making criteria is likely to be significantly more expensive than influencing at most a few hundred manufacturers with only one decision-making criterion.

3.2.2 Relatively Easy Monitoring and Evaluation (M&E)

The payment of incentives to manufacturers will be based on the number of efficient appliances that are sold to consumers, using a deemed savings approach. This will be relatively easy to monitor using excise tax records, as we discuss later. In contrast, for utility-administered programmes, regulators often require that causality for the energy efficiency savings be established, requiring more detailed evaluation carried out separately by each utility.

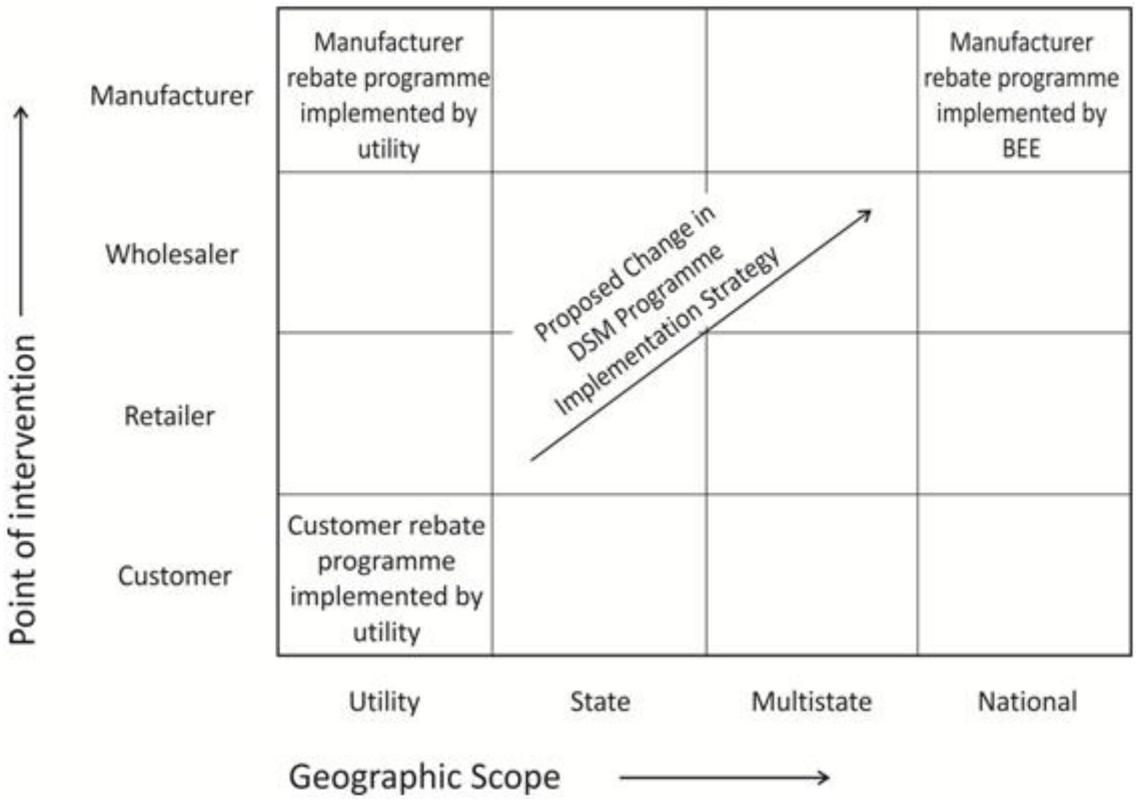
3.2.3 Introduction of Super-Efficient Products and Products Better Suited to Indian Conditions

There are many products that are based on designs that may not be best suited for Indian conditions. For example, in some areas with low voltage, tube-lights do not operate well. Manufacturers of such products do not have sufficient incentive to design and market products suited for Indian conditions. This is because they do not expect a sufficiently large market initially, which would translate to higher prices, which in turn keeps the market for such appliances small. In such cases, an upstream incentive programme can facilitate the development of appropriately designed appliances.

3.2.4 More Rapid Ratcheting of Standards and Labels

SEEP and the already established Standards and Labelling (S&L) programme should not be seen as competitors or as substitutes. On the contrary, they have complementary roles. The S&L programme pushes up the floor of performance, while SEEP will pull up the ceiling level. S&L is already mandatory for some appliances and is likely to be mandated for others soon. Because of the mandatory nature of S&L, there is a limit to which performance thresholds can be pushed up. In contrast, SEEP is voluntary and therefore, the thresholds can be pushed up more rapidly. Only those manufacturers with a capability and inclination to produce energy efficient appliances will be incentivised. Interestingly, as SEEP moves the market towards greater efficiency, the S&L programme will be able to ratchet up the performance thresholds more quickly.

Figure 2: Comparison between SEEP and Utility-Administered Programmes



3.3. Reasons for Selecting Fans for the First Programme under SEEP

There are two primary reasons for selecting ceiling fans for the first programme under SEEP. First, almost every electrified household in India has at least one ceiling fan. After the electric light, the ceiling fan is the most prevalent electrical appliance in Indian households. Consequently, any improvement in ceiling fan efficiency will benefit people from all socio-economic strata. Second, in spite of its almost universal presence in households, the ceiling fan has so far been overlooked and rarely mentioned in discussions on energy efficiency. Most ceiling fans sold in the country are of very low efficiency, even though there are alternative technologies available which can be used to dramatically improve the efficiency at a reasonable cost.

About 40 million fans are manufactured in India every year. Leaving out table and pedestal fans as well as units exported, about 25 million ceiling fans are sold in the country annually. With the market growing at 10% per year, more than 70% of the ceiling fans in use in 2020 will have been added in the period from 2010 to 2020. Since fans are rarely replaced, this new stock will have a long life. Therefore, it is important that this new stock be efficient (Singh et al., 2010).

Another reason for the selection of fans for the first SEEP programme is the significant market share of the organised sector. Eight leading brands – Bajaj, Crompton-Greaves, Havells, Khaitan, Orient, Ortem, Polar and Usha – together control about 70% of the market. Smaller and local manufacturers control the remaining 30%. With fewer manufacturers, it should be possible to bring about a rapid improvement in the efficiency of fans.

4. Programme Design

This section discusses four major components of the design of SEEP for fans: (1) the technical specifications for fans to qualify for the programme; (2) the process for determining the incentive level and the level so determined; (3) the framework for evaluation of the programme, monitoring and verification of the number of SE fans sold, and their performance (EM&V); and (4) the eligibility criteria for participating manufacturers.

4.1. Technical Specifications for SE Fans

The technical specifications for SE fans were defined after considerable discussions with manufacturers, both in one-on-one meetings and collectively as part of the consultations with stakeholders.

While deciding the specifications, we kept in mind the primary objective of SEEP, which is to achieve rapid market transformation to super-efficient variants of appliances. The aim was not simply to introduce the most efficient ceiling fan in the market, but to strike the best balance between cost and efficiency. It was also felt that the specifications should lie within the manufacturing capabilities of producers in India. A 70% market penetration of 35 W fans would be more desirable than a 1% penetration of 10 W fans.

Efforts were also made to set technology neutral specifications for SE fans. The specifications were selected such that innovators and manufacturers could exercise their ingenuity to devise alternative ways to meet them. In the case of fans, performance can be dramatically improved in different ways: (1) improving the induction motor; (2) using a BLDC motor; and (3) improving the design of the blades. The specifications for SE fans were developed to give designers and manufacturers freedom in how they chose to improve the performance relative to fans currently available in the market.

This involvement of manufacturers is described in more detail in the next section. Also, the Prayas team had interacted with retail sales-people about consumer preferences during our earlier work on fans (Singh et al., 2010). This interaction with salespeople indicated that consumers were not very interested in energy efficient fans. Price was a major factor in their decisions to purchase fans. The very low sales levels of 5-Star fans support this observation. It seems that consumers are most interested in high air delivery. Further, some sources indicated that there was a greater drop in air delivery at lower voltages for 5-Star fans compared to regular fans, which may also be contributing to the low sales volumes for 5-Star fans.

Given these features of the fan market in India, it seemed that a superior fan which was not only much more efficient but also addressed some of these concerns through superior performance would be optimal, i.e. a super-fan rather than just a super-efficient fan. Based on these considerations, the initial set of proposed specifications was defined as follows:

- Higher air flow at full speed (~230 cmm versus 210 cmm in the labelling program);
- Low noise through the use of better quality blades;
- In order to be more suitable for Indian conditions:
    - None or very low degradation in performance at lower voltages;

  - Reliable even under high ambient temperature;
- Lowest power consumption reasonably possible.

However, manufacturers were not supportive of the idea of a super-fan. According to them, it was difficult to establish how much air flow consumers want. Despite this, there seems to be a general perception that 210 cmm is acceptable to consumers. BEE's labelling programme requires 210 cmm, which is higher than the 200 cmm air flow required by BIS for fans. They were also apprehensive about the availability of the technology required to meet the specifications of the 'super-fan', because according to them, there was no working model that consumed less than 40 W and met the current airflow requirement of 210 cmm.

Given the manufacturers' hesitation, it was decided that at this stage, it would be best to maintain the requirement of 210 cmm and not impose any performance requirements at lower voltages. This would get the programme rolling, and super-fans can be introduced later. However, in order to encourage the production of fans with higher air flow, it was decided to specify a minimum service value rather than the maximum power consumption by the fan.[4] Further, it should be noted that if a BLDC motor is used for a SE fan, the drop in speed is likely to be less than a fan using an induction motor. This is because for BLDC motors, the speed is linearly related to voltage, whereas for an induction motor, the speed is related to the square of the voltage. Of course, if an induction motor is used for a SE fan, the drop in speed with voltage is likely to be the same as that for a regular fan. In any case, the drop in speed and air flow with a drop in voltage is not likely to be any worse than in case of a regular fan.

Following the interactions with manufacturers, technical specifications for super-efficient fans were selected, which are discussed in the following sub-sections.

4.1.1. Service Value

5-Star fans are required to have a service value greater than 4. So the service value (SV) for a super-efficient fan should be considerably higher. There are ceiling fans available in USA such as Eco Motors which consume 24 W at full speed and have a SV of 8.75. However, they are very expensive and have an air delivery considerably less than 210 cmm. Interactions with manufacturers also revealed that some BLDC fans available in India consume more than 40W. As discussed earlier, the objective of SEEP is to achieve market transformation, and not to introduce the most efficient ceiling fan in the market. With this in mind, it was decided to set the minimum SV at 6, which would result in a power consumption of 35 W at airflow of 210 cmm. If the airflow of the fan is higher, then the power consumption would be proportionately higher. As discussed earlier, this is acceptable because the efficacy of the fan measured by its SV will still be maintained. It should be noted that even though an SV of 6 is lower than the initial target based on fans available in the US, this SV results in the super-efficient fan having a power consumption that is half of that of a regular fan. Even in comparison with a 5-Star fan that has an SV of 4, a super-efficient fan would have an SV that would be 50% higher.

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[4]Service value is a measure of the efficacy of a fan, and is calculated by dividing the air flow in cubic meters per minute (cmm) by the power consumption of the fan in Watts. Generally, one can specify a minimum air flow, and either the service value or the power consumption. If maximum power is specified, then if a manufacturer produces a fan with the same efficacy but higher air flow, he would suffer a penalty because the power consumption would also be higher.

4.1.2. Power Factor

Technologies such as BLDC motor fans use electronics which can affect the power factor (pf) of the fan, which makes it necessary to specify the minimum pf for the super-efficient fan. Some stakeholders pointed out that fans sold in the market currently use induction motors and routinely have a pf better than 0.95. These stakeholders argued for a similar threshold for super-efficient fans. However, some manufacturers stated that while a high pf was easy with induction motors, it was more difficult to achieve with BLDC motors. It was decided to set the minimum pf requirement at 0.9 so that the minimum performance required would not be degraded, while not making it too difficult and expensive to produce. This is in accordance with BIS standards for ceiling fans, IS 374. The relationship between the pf and the harmonic distortion is discussed later.

4.1.3. Test Protocols

Protocols for testing fans have been established for the labelling programme for fans. The same protocols can be used for SEEP for fans. However, some concerns have been raised by manufacturers about the repeatability of the tests. In particular, a fan may meet the specifications at the manufacturer's facility, but fail to do so when tested for BEE at another location, say at a Central Power Research Institute (CPRI) lab in Bangalore. Two reasons seem to underlie these concerns: (1) the ambient humidity, temperature and air pressure are likely to vary with location resulting in varying density of the air, leading in turn to varying power consumption, because heavier air requires greater power to move it; (2) the test protocol as described in IS-374 requires the use of analogue anemometers which are no longer available in the market. Therefore, manufacturers use digital anemometers at their test facilities which can indicate different readings. The revision (still in draft) for IS-374 has prescribed testing protocols for digital anemometers. It needs to be formalised soon.

There can be two possible solutions to the issue of variation in performance due to different ambient conditions. One way is to specify a correction factor for variations of temperature, pressure and humidity. All revisions of IS-374 since 1979 have noted this point, but no action has been taken so far. Another possible solution is to specify that the fan must meet the service value (and hence power consumption) specification in the most stringent condition which would be when the air is cold and dry and hence the most dense. However, establishing and maintaining these ambient conditions for the duration of the test will require changes to test facilities and IS-374 which sets the protocol and test conditions. This issue needs to be sorted out before the launch of SEEP, as the fans to be incentivised will be selected using these protocols. Also, the issue is applicable not only to SEEP but to the labelling programme as well. Therefore, we hope that BEE and Collaborative Labelling and Appliance Standards Program (CLASP), a not-for-profit organization working with BEE on several issues related to S&L, will develop the required changes to the testing protocol.

4.1.4. Warranty

It is important to ensure that SE fans do not fail prematurely, negating the benefits for which the government and the customer have paid. Furthermore, because BLDC motors use electronic components, the issue of premature failures becomes even more relevant. Currently, fan manufacturers usually give a two year warranty, although some of them give a much longer warranty. It was felt that maintaining a two year warranty was sufficient. Electronic components which are likely to fail usually do so in the early life of a product, and a two-year warranty would cover such failures.

4.1.5. Reducing Electromagnetic Interference from Fans

If BLDC motors are used in SE fans, because of the electronic switching in the controller, there could be electromagnetic interference which may affect the functioning of other sensitive equipment on the lines. As large numbers of these fans are installed, the problem would need to be addressed.

For BLDC fans, the problem could come from two sources: (1) harmonics of the line frequency because of the rectifier; and (2) high frequency disturbance due to the switching in the inverter.

4.1.6. Limits on Harmonic Currents[5]

Limits on harmonic currents are set by Part 3 of the *Indian Standard on Electromagnetic Compatibility* (IS 14700 (Part 3/Sec 2): 2008). For limits on harmonic currents, equipment is divided into four classes, Class A through D. Household appliances such as fans are included in Class A. However, the standard does not set limits for equipment with a rated power of 75 W or less, other than lighting equipment. According to the standard, this limit may be reduced to 50 W. In either case, the standard would not be applicable to SE fans which will have a power consumption of less than 35W. However, in the public interest, we may want to limit harmonic currents anyway, particularly if these fans are likely to be installed in large numbers.

The true power factor and total harmonic distortion (THD) are related (See Box). The current requirement for the pf is at least 0.9. Effectively, this also limits THD to a maximum of 50%. We expect that this level of harmonic reduction can be achieved by the addition of passive components (capacitors and inductors) which are relatively inexpensive. If the requirement for the pf is to be made almost unity, expensive active components will be required.

4.1.7. Limiting High Frequency Interference

The *Indian Standard on Limits and Methods of Measurements of Radio Disturbance Characteristics* (IS 6873 (Part 2/Sec 1): 2012) is the standard that sets limits on the conduction and radiation of high frequency disturbances from household appliances, and is based on CISPR[6] 14-1. Reducing conducted emissions requires the use of an EMI filter, and reducing radiated emissions requires metallic shielding. Both these can be expensive, particularly in small quantities. As we discuss next, we believe that we do not need to specify these limits at this stage, but may introduce them later when the programme matures.

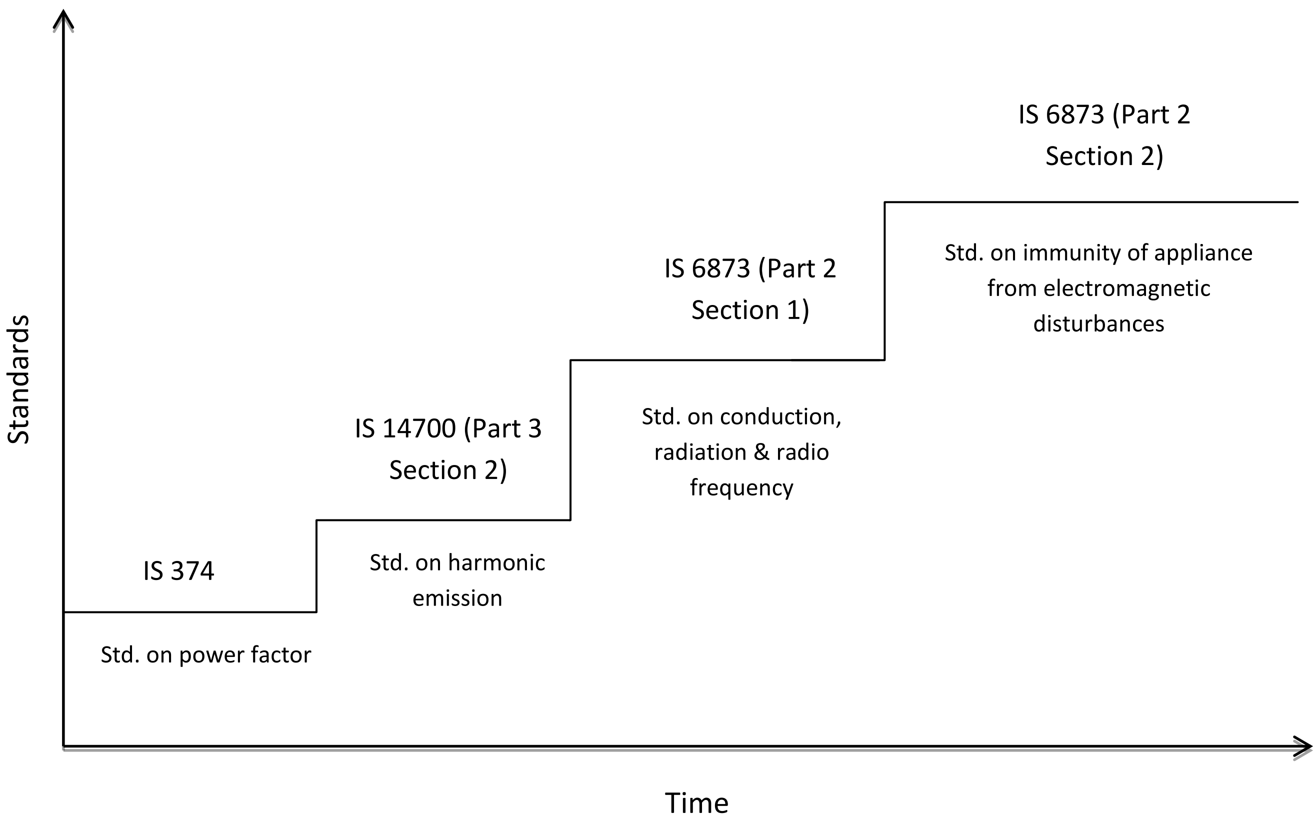
4.1.8. Suggested Approach

Reducing harmonics and high frequency interference is clearly a worthwhile goal. However, these efforts will add to the cost of the SE fan. Therefore, it is desirable to use a graduated approach to reducing harmonics and interference, as shown in Figure 3. Initially, only a minimum value of 0.9

[5]Harmonic currents are sinusoidal currents with frequencies that are whole multiples of the frequency at which the supply system is designed to operate. They appear on the electric power systems as a result of non-linear electric loads and are a frequent cause of power quality problems.
[6]CISPR is the Comite International Special des Perturbations Radioelectriques or, in English, the International Special Committee on Radio Interference

has to be specified for the pf. True pf and harmonics are related issues (See Box). Even though individual harmonics will not be specified explicitly, the THD will be limited to 50% of the fundamental because of the relationship between the true pf and THD. At the same time, manufacturers will be able to keep the cost of the fan down, and this will get the programme rolling. Later, as manufacturers gain more experience with SE fan technology and the product becomes accepted in the market, the specifications can be tightened by either raising the threshold for the true pf or providing a separate limit on individual harmonic currents. Subsequently, limits can be set on high frequency interference.

Figure 3: Suggested Approach for Reducing Electro-Magnetic Interference over Time



4.1.9. Summary of Specifications for SE Fans

The following table summarises the technical specifications for SE fans to participate in SEEP.

Table 2: Specifications for SE Fans

Performance Parameter	Required Level
Minimum air delivery at rated voltage	210 cmm
Minimum service value at full speed	6
Minimum power factor	0.9
Minimum warranty	2 years

Power Factor and Harmonics

Power Factor (pf) is defined as:

$$pf = \frac{Power\ consumed\ by\ circuit\ (W)}{V_{rms}\, I_{rms}}$$

In the past, most electrical loads, such as motors and incandescent bulbs, were linear. In such cases, both the voltage and current were sinusoidal and the pf was simply

$$pf = \cos\varphi$$

Where φ is the angle between the voltage and current. However, with greater use of electronic loads such as power supplies and adjustable speed drives, harmonics are produced which distort the waveform, and the pf is no longer simply equal to $\cos\varphi$.

Starting with the definition of pf, it can be shown that with harmonics present, the pf is given by:

$$pf = \frac{Power\ consumed\ by\ circuit\ (W)}{(V_1 I_1)\left(\sqrt{1+THD_v^2}\right)\left(\sqrt{1+THD_i^2}\right)}$$

Where V_1 and I_1 are the rms values of the fundamental component of voltage and current, and THD_v and THD_i are the total harmonic distortion of the voltage and current respectively. Generally, voltage harmonics are very small and can be neglected, resulting in the simplified expression:

$$pf = \frac{V_1 I_1 \cos\varphi}{(V_1 I_1)\left(\sqrt{1+THD_i^2}\right)}$$

$$pf = \frac{\cos\varphi}{\left(\sqrt{1+THD_i^2}\right)}$$

Which can be written as:

$$pf = pf_{displ} * pf_{dist}$$

where pf_{displ} is the displacement power factor which is due to the displacement of the fundamental of the current and voltage and is equal to $\cos\varphi$, and pf_{dist} is the distortion power factor due to harmonics.

By limiting the pf to 0.9, even when pf_{displ} is at its maximum value of unity, pf_{dist} cannot exceed 0.9. Because a THD of 50 % results in a pf_{dist} of 0.9, we are limiting the THD to 50%. If pf_{displ} is less than unity, as it is likely to be, then THD will be even less than 50%.

It is important that during testing, the true rms values of voltage and current and the true pf are measured. Less expensive meters often measure average current and then apply a form factor to get the rms value. This method is appropriate for sinusoidal waveforms, but with harmonics present, it can result in erroneous results.

Source: Grady and Gilleskie, 1993

4.2. Process for Determining Incentive Level

Setting the level of incentive to be provided to manufacturers was one of the key decisions in the SEEP programme for fans. In general, there are two approaches to determining the incentive: (1) through competitive bidding to 'discover' the lowest incentive that would be required by manufacturers; and (2) thorough analysis and discussion to determine the incremental manufacturing cost.

Under competitive bidding, the specifications for super-efficient fans would be announced, and bids would be solicited from interested parties for selling such fans in the Indian market. The bidders would quote the minimum incentive they would require, and the party with the lowest bid incentive would win.

In an approach through analysis and discussion, the incremental cost of making super-efficient fans would be estimated through analysis, and the incentive level set accordingly. Any manufacturer could participate in the programme at any time, and would get the same incentive as any other manufacturer.

In order to select a process to determine the incentive level that should be offered for SE fans, the advantages and disadvantages of competitive bidding are compared with those of using an analytical estimate below. While comparing these two approaches, it is important to remember that the intent of the process is not simply to reduce costs for SE fans down to the bare minimum. While low cost is certainly desired, the main objective of SEEP is to maximize the savings at a reasonable cost, and facilitate a rapid market transformation by taking most of the manufacturers along.

4.2.1. Advantages of Competitive Bidding

- Competitive bidding would help in the 'discovery' of the best technology and the lowest cost approach to meet the desired specifications of a super-efficient fan.
- Bidding would reward innovators and risk-takers because they would be more likely to win in the bidding process.
- Bidding would be an easier way to estimate the incremental manufacturing cost, because only a preliminary analysis will be required to estimate a reasonable range for the bids. No negotiations with manufacturers would be required. In contrast, under the analysis based approach, the incremental manufacturing cost for SE fans would need to be estimated. Because of information asymmetry between manufacturers and BEE, it would require an additional effort to arrive at a reasonably accurate estimate of the actual incremental costs.
- Bidding would be consistent with many government procurement processes where tenders are floated, and the lowest quoted price wins the contract to supply the particular good or service. Once a competitive bidding process is complete and the winning bidder selected, no additional checks would be required by the government, resulting in speedy implementation of the programme.

4.2.2. Disadvantages of Competitive Bidding

- The common form of bidding would result in a single manufacturer supplying the SE fans. This would be risky because if the winning bidder were to default, the programme would come to an end. Therefore, we would have to devise ways so that we don't put all our eggs in one basket. However, we also realise that it would be possible to have more than one supplier of SE fans if the bidding system were designed differently. One method would be to give the winning bid his bid level of incentive, but give the other manufacturers a somewhat lower incentive (say 10-20% lower). The rules for such a process would need to be developed.

- In any case, if only one or a small group of manufacturers participate in the programme for SE fans, the overall savings of energy would be reduced. The more manufacturers that participate in the program, the greater the number of SE fans sold, and consequently the greater the energy savings. This could be a significant disadvantage for competitive bidding, because a major aim of the programme is to maximise energy savings.
- Non-participating manufacturers could sabotage the programme and the product through false propaganda.

Rather than look at these two options in an either/or way, it was decided to combine the advantages of both approaches. The following hybrid approach proposed for SEEP for fans attempts to do just that.

1. Set an incentive level based on an estimate of the incremental manufacturing cost. For the first year, all manufacturers would be eligible for the same level of incentive.
2. In the second year, all manufacturers would still be eligible for a uniform incentive, but it would be lower by say 25%.
3. In the third year, the incentive would be based on bidding. The lowest bidder would be eligible to receive his bid, while all the others would be eligible for a slightly lower incentive by say 10-20%.

This approach would allow the programme to start quickly and reduce chances of the programme being derailed. By organising bidding in the third year, it will be ensured that incentives are not more than necessary.

4.3. Estimation of Uniform Incentive for the First Year

Having decided on the process for determining the incentive level, we estimated the incremental manufacturing cost of a super-efficient fan through a bottom-up analysis. We also assessed the cost-effectiveness of increasing levels of incentive by comparing the cost involved with that of generating electricity.

4.3.1. Bottom-Up Analysis of Incremental Manufacturing Cost of SE Fan to Determine Incentive Level

Based on interactions with several manufacturers and other experts, it seems that an SE Fan that consumes 35 W or less will most likely use a brushless DC (BLDC) motor. Therefore, our estimate of the incremental cost was based on the costs of a BLDC motor for the fan. We recognise that this may seem to contradict technology neutrality which we mentioned earlier. However, for setting an estimate we have had to base it on the technology most likely to be used. If someone uses another technology such as an improved induction motor that costs much less, he would have a much larger profit. Unlike induction motors, BLDC motors require an electronic controller. Therefore, for estimating the manufacturing cost of a BLDC motor one needs to include the costs of the motor and controller, and compare their total cost with the cost of an induction motor for the fan.

A commercially available sub-50 W BLDC motor was analysed to estimate the costs for an SE fan based on a BLDC motor. An expert in design and manufacturing in power electronics was asked for a cost estimate for the BLDC controller. Based on the components used in the controller and a detailed estimated bill of materials, he estimated the controller to cost about Rs 320 if it were manufactured in large volumes. Another expert with experience in motor design and manufacture estimated the motor costs excluding the controller. He estimated that the incremental cost of a BLDC motor (excluding controller) for a fan would be in the range Rs 0 to 75 depending on the magnet material used and its price which can be very volatile. Putting the two estimates together, the incremental cost for the BLDC motor including controller is expected to be in the Rs 320 to 400 range. BEE has also requested cost estimates from fan manufacturers and developers.

4.3.2. Assessment of Cost-Effectiveness of Different Incentive Levels

The cost-effectiveness of any energy efficiency measure can be assessed by comparing the cost of conserved energy (CCE) with the cost of the electricity that is saved by the measure. The cost of conserved energy is calculated by annualising the cost of the measure over its life, and dividing the annual cost by the annual energy saved, which will give the CCE[7] in Rs/kWh. Figure 4 shows the CCE for SE fans for incentive levels varying from Rs 100 to 500 per fan. Even with an incentive of Rs 500 per SE fan, the CCE is well below the total cost of generation, and even below the fuel cost for generating electricity. For instance, the CCE at Rs 300 incentive is about 0.63 Rs/kWh as compared to the total cost of generation, 2.3 Rs/kWh. The savings from SE fans can be large. If a million fans are installed in one year with an incentive of Rs 300 per SE fan, more than Rs 60 crores worth of fuel will be saved over the life of the million fans, after paying back the incentive amount. We have not considered the increase in prices of fuel which will further increase the savings. If we include the capital costs in generating electricity, the savings would be Rs 160 crores. That means that delaying SEEP programme for a year, even for a million fans, can result in a total loss of Rs 160 crores over the life of those fans.

4.4. Evaluation, Monitoring and Verification (EM&V)

A deemed savings approach will be used for SEEP, and incentives will be based on the number of SE fans sold by manufacturers. The EM&V needs to address two concerns: (1) the validity of the number of SE fans sold by each manufacturer; and (2) the quality and performance of SE fans sold under the programme. Figure 5 shows the proposed framework for verification of the number of SE fans sold. Every month, the manufacturer will file a claim, certified by his Chartered Accountant (CA), for the number of SE fans that left the factory gate that month. The manufacturer will be paid based on this claim. However, at the end of the year, the claimed number will be cross-checked against the excise records. Any difference between the annual total claimed by the manufacturer, and the number of SE fans for which excise was paid, will be made up by en-cashing a part of the bank guarantee that the manufacturer gave when signing on to the programme, or deducted from future payments. More details about the bank guarantee are provided in section 6 on programme

[7]All calculations are based on an average annual usage of 1800 hours. This is a conservative assumption to account for the diversity factor in the usage.

implementation later. The monitoring framework must ensure that SE fans for exports are not included in the claims by manufacturers for incentives. BEE and the implementation agency will need to devise a mechanism to ensure this. Also, a central database will be put in place to collect text messages from customers, who will be encouraged to send them by way of a lottery based scheme. In this manner, customer feedback for the super-efficient fan will be gathered.

Figure 4: Cost-Effectiveness of Different Incentive Levels for SE Fans

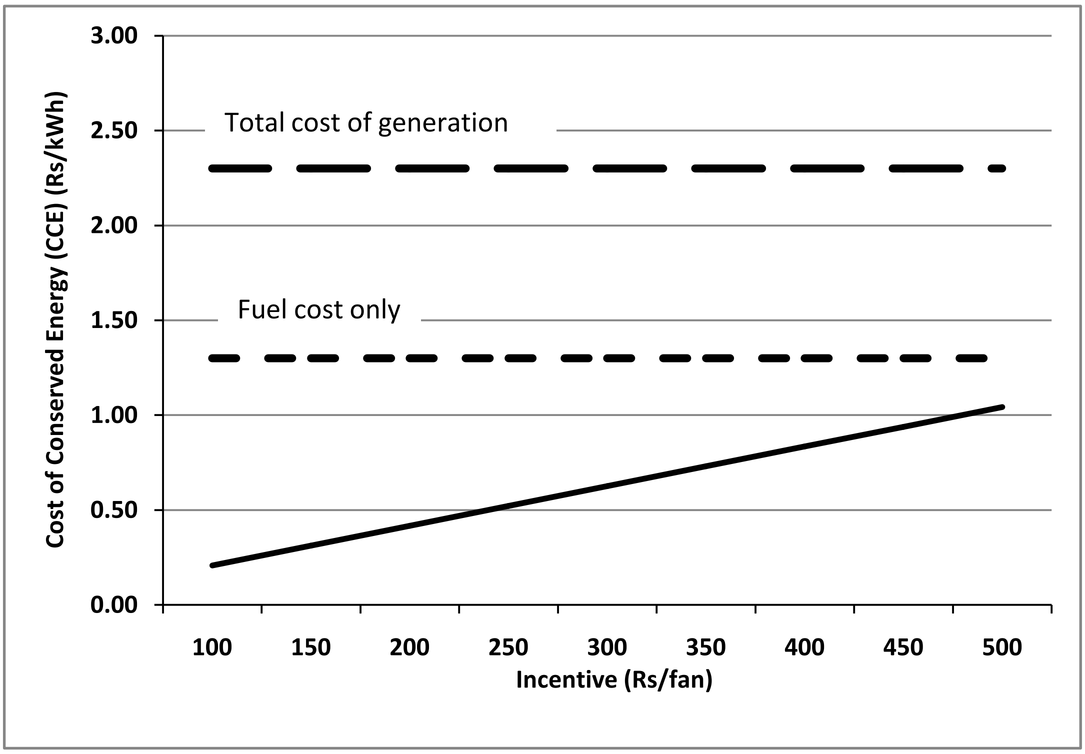


Figure 5: Framework for Verification of Number of Fans Sold

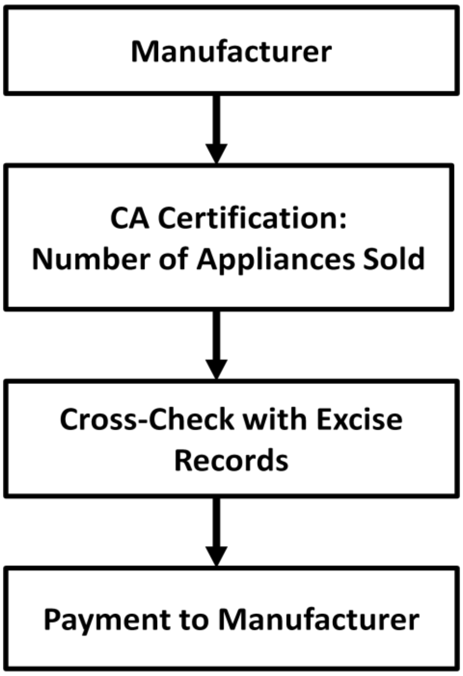
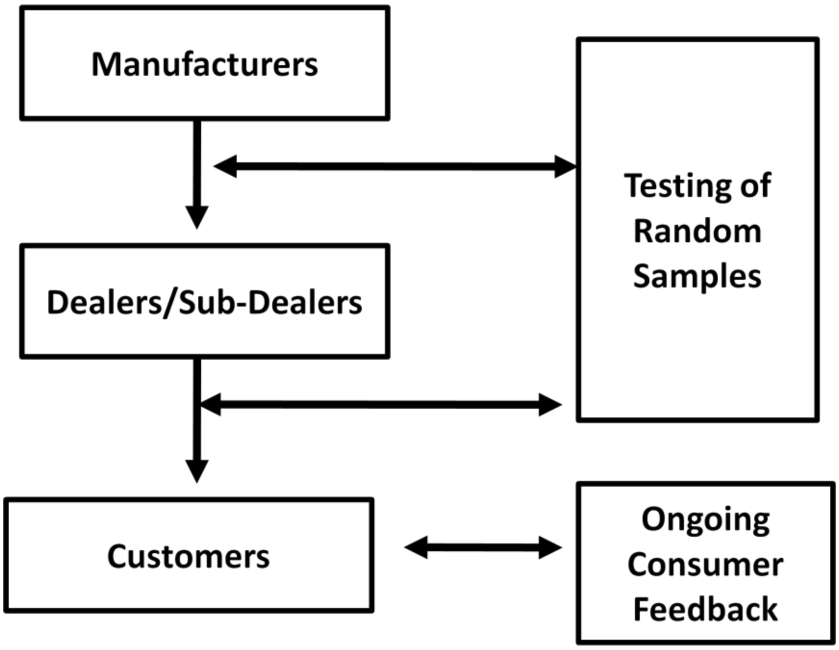


Figure 6 shows the measures proposed to be adopted to ensure that the quality and performance of the SE fans meet the required specifications. The BEE already tests random samples to check the validity of labels under its S&L programme. Therefore, these measures would not be particularly burdensome.

Figure 6: Framework to Ensure Performance of SE Fans



4.5. Eligibility Criteria for Participating Fan Manufacturers

The goal of SEEP being a rapid market transformation, the need for a mechanism to ensure that manufacturers have the capability to successfully and vigorously participate in the programme emerged. Further, it was felt that the eligibility criteria should reduce the entry of 'fly-by-night' operators who would introduce spurious products which would be detrimental to the success of the programme. This meant that participating manufacturers would need the capability to manufacture SE fans, an extensive dealer and retailer network to effectively market SE fans throughout the country, and a strong brand image that they would want to protect by producing and selling good quality SE fans. At the same time, because the programme required innovation, restrictions on participation by interested manufacturers would have to be kept to a minimum.

In this context, it was decided to have a single criterion for participating manufacturers – minimum annual sales of 3 lakh fans over the last three years. 3 lakh fans represent about 1% of the market for ceiling fans. There was concern about the impact on innovators and small manufacturers who can often be the drivers of change in an industry. It was felt that this criterion would not be too onerous for them because, in any case, innovators would need to team up with established manufacturers to manufacture and market their products.

5. Collaborations and Partnerships

As with any other programme, the success of SEEP requires the involvement of all relevant stakeholders. SEEP has been the result of collaboration between several stakeholders from different arena. These collaborative efforts have been key in taking the programme forward, and will be critical for its future success.

5.1. Government Agencies

Introduction of a new programme requires the assent as well as the active support of relevant government agencies. It was fortuitous that soon after we described the concept of using upstream incentives for a rapid market transformation to super-efficient appliances to the DG-BEE and his staff, they took up the idea enthusiastically. BEE arranged meetings with chairmen of select SERCs and the CERC in September 2009. The programme also received the support of Forum of Regulators (FoR), through the Chairman, CERC. Subsequently, we developed the implementation framework for SEEP, and BEE was very open to accepting our help and suggestions. We also developed the overall programme design described in detail in this document, consisting of the technical specifications, process for determining the incentive level and the actual level, qualifications for manufacturers to participate in the program, and the EM&V framework.

5.2. Fan Manufacturers

Appliance manufacturers are one of the key stakeholders in the implementation of SEEP; without their participation there would be no programme. Fan manufacturers were forthcoming in expressing their concerns when we met them first at a meeting of the Technical Committee for Fans, and later in our meetings with individual manufacturers. During the stakeholder consultation described in sub-section 5.4, they presented their views on the proposed technical specifications, EM&V and other aspects of SEEP for fans. Their participation in these discussions has helped shape the programme such that it addresses their concerns while ensuring significant public benefits.

5.3. Other Partners

We have benefited from collaboration with the Lawrence Berkeley National Laboratory (LBNL) and the Regulatory Assistance Project (RAP). After we developed the concept of national programmes with upstream incentives, LBNL and RAP extended this concept to the international level, and developed the Super-Efficient Equipment and Appliance Deployment (SEAD) program. SEAD seeks to use the bargaining power of the International Partnership for Energy Efficiency Cooperation (IPEEC) member countries to improve the efficiency of appliances traded worldwide. LBNL and RAP have also provided analytical support for the inclusion of other appliances in SEEP. The Shakti Sustainable Energy Foundation (SSEF) has supported the development of SEEP.

5.4. Public Consultations

BEE organised stakeholder consultations with fan manufacturers and others to discuss technology options and to get their feedback on issues related to the implementation of the programme, such as incentive structure, technology adaptation, evaluation and monitoring, etc. Based on our earlier work, the Prayas team worked with BEE to develop an initial proposed implementation framework covering these issues. The responses and suggestions from the stakeholders were incorporated in the initial framework to arrive at a final implementation framework.

However, SEEP is a national level programme, has no precedent in India, and will be the biggest programme run by BEE. Hence, it is important to provide an opportunity to a broader section of society to critique the programme, and take their views into consideration. For this purpose, it is desirable to hold a public consultation with civil society organisations and other public members involved in energy efficiency.

6. Programme Implementation

6.1. Framework for Implementation

With the completion of the phase of programme design, as discussed in section 4, the next major phase for SEEP for fans is its implementation. Figure 7 lays out a framework for implementation, with its middle section indicating the sequence of required steps.

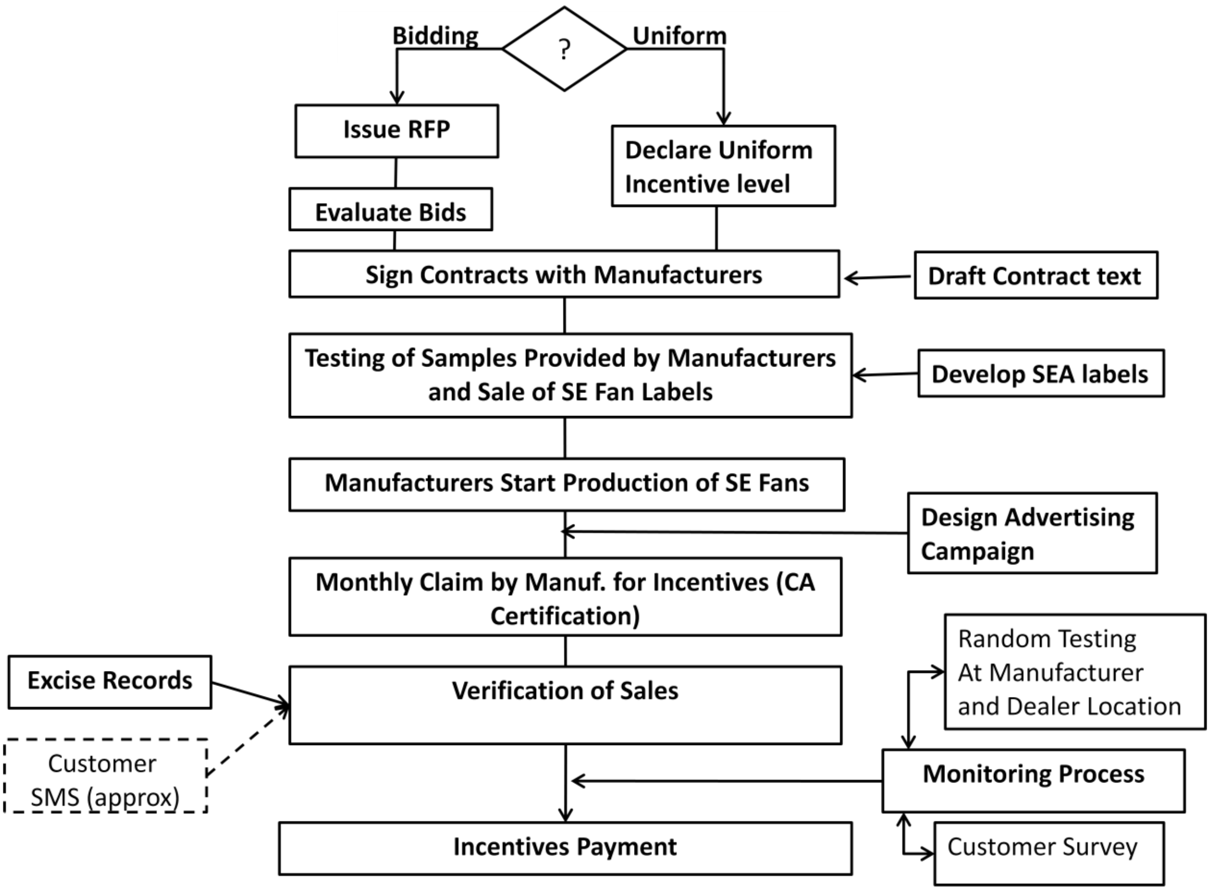
- After the programme is announced and participation invited, applications from interested manufacturers will need to be scrutinised to ensure that they meet the minimum qualifying criteria for participation.
- Qualified manufacturers will be asked to submit samples of SE fans which will be tested. Manufacturers whose fans pass the certification process will be included in the programme. As discussed in the section on EM&V, claims for the incentive will be paid monthly, but the reconciliation with excise records will only be done annually. In case of a discrepancy between the manufacturers' claims and the excise records, a mechanism must be put in place to recoup losses. Therefore, fan manufacturers will need to provide a bank guarantee to cover any discrepancies between their claims and excise records for the year.
- Participating manufacturers will start producing SE fans and submit monthly claims for the incentive. The claims will have to be certified by their CA.
- Monthly claims will be paid with a provision for correction at the end of the year.
- At the end of the financial year, the total claims for the year will be reconciled against excise records for each manufacturer. Any discrepancy will be corrected either through deductions from future claims, or from payments based on the bank guarantee provided by the respective manufacturer.

In addition to these steps, other supporting actions will need to be taken as well, which are listed to the left and right of the main sequence of steps in Figure 7. These actions are:

- A label for SE fans will need to be developed to inform customers, to distinguish between labelled fans with different star ratings from 1 to 5, and to identify SE fans.
- In addition to advertisements by manufacturers of SE fans, BEE should initiate an awareness campaign to promote these fans. The campaign should inform consumers about the programme and the expected benefits in terms of savings from SE fans.

- As discussed earlier, the performance of fans with SE labels in the market will be monitored to ensure that spurious products are not being sold. To this end, random samples from the market will be tested.
- As discussed earlier, a central database should be put in place to record customer information through text messages (SMS) as soon as they purchase SE fans. Customers should be encouraged to send such messages through a lottery scheme, or a small financial incentive to the retailer to encourage the customer to send a text message. This mechanism needs to be developed.
- The registration of sales of SE fans by text messages would provide a list of customers who have purchased SE fans, which could then be used for quick customer surveys either by phone or in person. Such surveys would provide additional information on the performance of SE fans in the market, and would help target additional testing for those manufacturers with whose fans customers were most dissatisfied. It will also provide insights into consumer behaviour, and be helpful for designing future programmes.

Figure 7: Implementation Framework for SEEP for Fans



6.2. Agencies and their Responsibilities

BEE is primarily responsible for making rules to promote energy efficiency. It has limited capacity to implement large scale EE programs such as SEEP on its own. Therefore, it will have to get other agencies onboard to assist with the implementation of SEEP. In order to implement SEEP for fans according to the framework described above, three additional agencies will be required to assist BEE. These three agencies are: (1) A Fund Management and Implementation Agency (FMIA); (2) A Monitoring Agency to assist with the monitoring of performance of SE fans in the market; and (3) An Advisory Committee consisting of representatives from various stakeholders to provide oversight. Table 3 provides details of the roles and responsibilities of each of these agencies in implementing SEEP for fans.

Table 3: Roles and Responsibilities of Institutions

Agency	Responsibilities
Bureau of Energy Efficiency (BEE)	- Programme design: tech specs; determination of incentive level and process for determination of incentive; - Overall supervision of the programme - Mass outreach - Reporting progress every six months to the Advisory Committee. - An annual third party evaluation of the programme
Fund Management and Implementation Agency (FMIA)	- Announcement and invitation to participate, issuance and evaluation of RFQs from potential participants and RFPs (if and when bidding is required) - Signing of contracts with selected manufacturers - Verification of production and sales data - Handling funds including disbursement - Creation and maintenance of customer database - Reporting to BEE
Monitoring Agency (MA)	- Spot performance checks of super-efficient fan models - Reporting to BEE
Advisory Committee	- Review of progress every six months, and suggesting measures to improve effectiveness of the programme - Review of the annual programme evaluation study

7. Lessons

There are several lessons to be gleaned from our experience in developing SEEP for fans that would be applicable to SEEP for other appliances, and more broadly, to other types of energy efficiency programmes in India:

- Involvement of key government agencies is crucial for the success of the programme. One of the reasons that SEEP for fans was able to advance quickly from its conceptualisation to implementation is the active involvement and support of BEE. Similarly, the programme also received the support of Forum of Regulators (FoR), through the Chairman, CERC. The support of BEE and FoR was instrumental in enlisting the support of the chairmen of key SERCs which have been interested in furthering energy efficiency in their states.

- Manufacturers must be involved early. The Prayas team has engaged in several individual and collective interactions with manufacturers. Such interactions are useful in several ways:
    - They help to assess initial interest in the programme, and can also help generate greater interest from manufacturers as they appreciate the benefits of the programme from subsequent interactions.
    - They help to understand the issues and concerns of manufacturers. For example, our interactions revealed how competitive the market was, and therefore, how important it was to keep the incremental cost of SE fans within reasonable limits.
    - They help in getting some estimate from manufacturers about the required incentive level from their perspective.
- The industry structure and market dynamics for the appliance must be understood. This helps in targeting efforts in the appropriate section of the industry. It also helps in understanding the concerns of the manufacturers better.
- Adequate attention must be paid to the availability of technology. In our early interactions with manufacturers, we learned about the state of the technology for SE fans. While BLDC fans were available internationally, they did not meet the air flow requirements for Indian consumers. Most manufacturers were not confident about the technology or their ability to modify it for Indian conditions. More generally, it is important to know whether SE models are available worldwide, and the efforts that would be required to acquire or develop the technology.

8. Potential Pitfalls and Challenges

While SEEP can greatly accelerate the market transformation to highly efficient appliances, there are some potential pitfalls that need to be avoided, and challenges that need to be addressed. Because of the centralisation of efforts, a failure of any kind will have much greater ramifications than a utility or state-administered programme with limited coverage. In order to tackle these concerns, much greater transparency will have to be ensured during implementation.

- Evaluation, Monitoring and Verification (EM&V): EM&V has to be designed carefully and implemented vigilantly. Particularly, attention will need to be paid to ongoing monitoring to identify problems as soon as they occur. This being a new programme designed with a novel approach, it is important that the monitoring agency is very vigilant in the initial phase of the programme, when unanticipated problems are more likely to arise. It will be extremely important to track consumer complaints about performance of the fans, particularly from a specific manufacturer or manufacturers, through customer feedback by text messaging.
- Effective Penalties or Deterrents: In order to prevent the sale of spurious products or false claims of sales of SE fans, effective penalties and other deterrents should be put in place, and manufacturers must be convinced that these will be enforced if defaulters are caught. Some possible deterrents are: (1) en-cashing of bank guarantee if fans do not meet specifications, or if false claims are made; (2) public announcement of default on product

quality or false claims by any manufacturer for the first offence, followed by black-listing of defaulting manufacturers from all BEE labelling programs on subsequent offence.

- Flexibility and Mid-Course Correction if required: If flaws are identified in the implementation framework in the process of monitoring, BEE must be prepared to make mid-course corrections.

9. Conclusions

SEEP is an innovative concept for the delivery of energy efficiency to achieve rapid transformation of the market towards super-efficient appliances. It could serve as a model not only for EE programs in India, but also for other developing countries that are striving to bring about a market transformation to efficient appliances, but have limited expert resources for energy efficiency programs. The programme for fans being the first one to be implemented under SEEP should be seen as a pilot for SEEP for other programmes. Though the programme has been designed carefully with inputs from all relevant stakeholders, this innovative programme which is the first of its kind in India may face some teething problems in the initial phases of its implementation. BEE and others must remain vigilant for potential problems, and must be prepared to implement mid-course corrections as and when required.

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