# Deployment of wind pumps throughout remote Indonesia: A survey of technical support

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## ABSTRACT

A survey of technical support has been carried out in order to assess the viability of widespread deployment of locally-made capillary wind pumps (PKMs) in the Mesuji-Tulang Bawang (MTB) subdistrict of Lampung, Indonesia. A list of desirable equipment for a facility was constructed by assessing the types of machinery that would be required in the event of failure of the various PKM components. Ten facilities in the region of the MTB were selected for the survey on the basis of their general experience in metal working and metal forming. The results of the survey showed that only 2 out of the 9 respondents had the equipment required to manufacturer/repair all the component groups of the PKM design, and even these facilities would have to outsource work for any part of the component group that required high precision machining. The results of the survey also show that a significant proportion of the workshops do not have accredited training programs, adequate calibration procedures and regular suppliers. Workshop managers are targeting three priority areas for improvement: inventory procedures, work safety standards and efficiency of operations. A set of key criteria, related to the provision of technical support for the PKM program, have been established and each facility was ranked against this set of criteria. The results of this analysis show that the Berkah, Dinamika Jaya workshops and the BLK Institute are in the best position to provide technical support to the PKM program, with the possibility of training being offered by Production Unila.

***Keywords – mechanical wind pump, water sanitation, remote village power, sustainable development, technical support***

## 1. INTRODUCTION

The Pijar Cendikiawan Foundation (YPC), an NGO in Lampung, Indonesia has obtained several research grants to develop a Capillary Wind Pump (PKM). The PKM program is part of the YPC mission to improve agricultural productivity, health and education for the remote villages in the Mesuji-Tulang Bawang (MTB) sub-district of Lampung. These villages have one of the highest rates of incidence of water-bourne diseases in Lampung (Dinas kesehatan 2006). In 2005, a demonstration of the PKM technology was installed in the village of Tanjung Menang in the Eastern region of the MTB sub-district in an attempt to use renewable energy to supply clean water to the village (Yudiantoro 2006). The YPC established a research station at Tanjung Menang and, through field observations, identified that the PKM program required further development in order for (a) the growth in the demand for water in the village to be met and (b) further PKM systems to be installed in the similar villages in the MTB subdistrict. A collaboration research project has been established between Murdoch University, Perth and the YPC to assess the options for use of renewable energy in the Eastern part of the MTB sub-district as a means of addressing the needs of villagers in the area for electricity and clean water. Part of this project is to assess the viability of the PKM program in the area. The YPC have promoted a comprehensive starting point for the PKM program by involving, in the pilot project, traditional farmers as end users, academics as designer of the PKM technology and manufacturers for constructing the PKM. Previous studies have shown, however, that there have been a number of common problems associated with small scale enterprises (SMEs) that are manufacturing renewable energy technology and providing support services. These problems can be summarised as quality, reliability and sustainability of both the product and the SME management system (Amin et al 2009, Ilskog 2008, Bruce 2008, Pope et al 2004, Taufik A 2007).

A number of important research questions have been constructed by Murdoch University researchers, such as:

(1) Is the installation of the PKM in Tanjung Menang an example of sustainable development?

(2) Are there sufficient resources to enable widespread deployment of PKM systems in remote villages throughout the MTB sub-district?, and

(3) To what extent can the PKM systems address the problems of water sanitation in the MTB district?

This paper highlights work from a study that deals directly with the second research question stated above. If the YPC were to conduct a program to deploy a number of wind pumps in Tanjung Menang and similar villages in the MTB subdistrict, then the success of this program would be dependent on the level of technological resources (e.g. equipment, materials, labour etc.) and technological expertise (e.g. trained staff) that are available. For a sustainable program, the correct procedures must be in place to maintain both resources and expertise.

The aim of this paper is to assess the level of technological resources and expertise that exists in the MTB sub-district to support the widespread implementation of PKM windpumps in the area. The scope of work for the paper was defined by the following objectives, namely:

(1) To identify and compile a list of potentially suitable facilities in the area that could provide technological support to a PKM program,

(2) To profile the facilities to establish the types of equipment they use that would be suitable for manufacture and/or repair of PKM components, and

(3) To assess the suitability of the facilities in terms of key criteria such as location, cost, and compliance with standards.

## METHOD AND PROCEDURE

### Identifying potential facilities

Potential facilities were selected from a database of small-to-medium enterprises published by the local government of the Lampung province (BPS Provinsi Lampung 2007). In the selection stage, 300 facilities across Lampung provinces were reviewed. Ten such facilities were chosen from the database with facilities ranging from workshops run by local businessmen to laboratories of Universities and Technical Colleges. These ten facilities satisfied the initial selection criteria that they must be suitable facilities with equipment for conducting general metal forming & manufacturing. The suitability of the facilities were determined from several indicators, including experience in metal cutting, profiling and welding and an ability for both turning and milling on the facilities machinery. The various component groups of the PKM are discussed in the next section.

## Establishing the desired equipment and services for a facility

Prior to profiling the potential facilities, the various components of the PKM and their failure modes were analysed to establish a list of desired equipment for a facility. The PKM was designed with four major component groups as depicted in Fig.1. To identify the failure modes of the PKM component, the method of FTA-*Fault Three Analysis* was adopted (Insan & Taufik, 2007). Assuming availability of sufficient wind and water resource (i.e. that the wind speed is above the cut-in wind speed of the PKM and that there is sufficient water depth to prime the pump), the FTA classified eight components that were open to failure; tower, gear box, blades, shaft, bearing, intake piping system, water pump set and discharge piping system. The mode of failure was examined for each component; the water pump set, for example, can fail due to structural damage or leaking or blocking at either the inlet pipe or discharge pipe. For each mode of failure, the equipment required to repair the damage or produce a replacement part was noted.

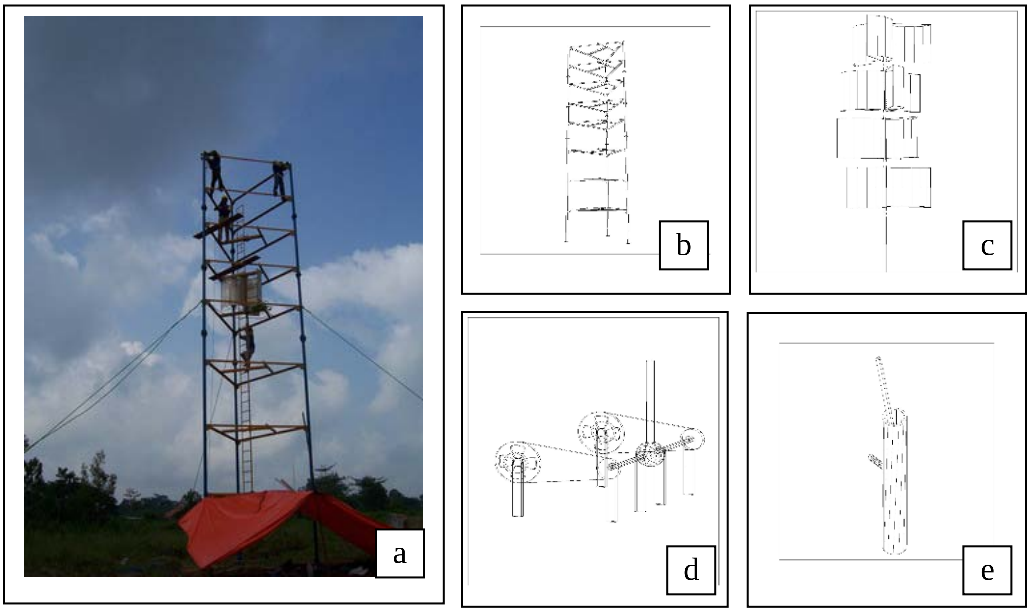


Fig.1. Component groups of the PKM wind pump: (a) overview, (b) tower, (c) blades, (d) transmission system and (e) water hand pump (Insan & Taufik 2007).

In this way a set of desirable equipment for a facility was established. This consisted of six main production machines (a lathe, a CNC machining tool, a welding machine, a cutter, a grinder and a profiler) and a set of useful support equipment (hoists/pulleys, spirit levels, electric metal polishers, trestles and grippers/clamps/lanyards). Also a set of desirable services that a facility could provide to support the PKM were defined. Examples of these were providing basic training programs for installation, operation and maintenance of the PKM, sending experts to site in order to repair some components or to do an overhaul of the PKM and sending parts to the capital city, Bandar Lampung, for high precision machining.

### Profiling potential facilities

The next step of the method was to profile the ten potential facilities to determine the exact nature of the equipment in the facility and to investigate the procedures that the facilities had in place to ensure competence and reliability. This step was carried out by surveying the managers of the facilities using both written questionnaires and semi-structured interviews. Ethics approval was gained for the survey for the Murdoch University Human Research Ethics Committee and an initial approach was made to each of the facilities to explain the objectives and procedure of the survey. In this initial approach, the PKM design was provided to each of the managers who were then asked about their facilities availability and ability to manufacture/repair the PKM. Before the survey commenced, a letter of consent was obtained from the managers. Nine out of the ten facilities agreed to take part in the survey, giving a response rate of 90%.

The survey of technical support consists of four parts. Part A and B of the survey are designed to compile data on the type of equipment available in the facilities. In particular a note was made of the equipment that matched the list of pre-determined desirable equipment and their potential to provide technical support to the widespread deployment of the wind pumps in the form of manufacturing and maintenance. Part C of the survey identifies the typical operation of the workshops, including training and calibration of equipment. Finally, Part D of the survey consists of interviews with facility managers concerning the plans that the workshop has for improvement of their operations.

## RESULTS

### Survey Part A and B

Tab.1 lists the nine facilities that participated in the survey. The facilities are classified as either workshops (W), institutions (I) or laboratories (L). Six out of the nine facilities are workshops run as businesses and were chosen as potential participants in the PKM program due to having experience in metal working, metal forming, cutting and welding as well as having at least two main production machines. One institution is included, the BLK (*Balai Latihan Kerja*), a non-profit, government run, technical training college. The BLK is used to provide training on metal working and metal forming and is open to the public, schools (mostly senior high level) and other community groups. The advantages of involving the BLK in the PKM program would be in access to adequate equipment and qualified instructors. Two laboratories from Lampung University complete the list, the Production Laboratory and the Computer Numerically Controlled (CNC) Laboratory of the Mechanical Engineering Department of the University. These are referred to as Production Unila and CNC Unila, respectively. The CNC Laboratory in Bandar Lampung is an exception to the list because it is the only facility that is located outside the MTB subdistrict. Some parts of the PKM, however, are high precision components (e.g. shaft, helical gear and valve griper) and thus the CNC laboratory was included in the list for its state of the art, high precision machining equipment.

Tab.1. Equipment profile of the workshops

| No. | Detailed Information | DJ | Bk | Ar | CM | Kr | An | BLK | PU | CU |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Workshops** | | | | | | | | |
| 1 | **General Information** | | | | | | | | | |
| | Type (W/I/L)* | W | W | W | W | W | W | I | L | L |
| | Experience (years) | 20 | 13 | 13 | 10 | 7 | 25 | 20 | 4 | 4 |
| | Number of labors/workers | 30 | 52 | 16 | 20 | 10 | 6 | 8 | 2 | 1 |
| | Total Numbers of main machine | 5 | 10 | 5 | 6 | 7 | 3 | 12 | 8 | 1 |
| | Total Numbers of support equipment | 17 | 17 | 9 | 17 | 8 | 5 | 20 | 10 | N/A |
| 2 | **Detailed Main Machines** | | | | | | | | | |
| | Lathe | 1 | 6 | - | - | 2 | - | 4 | 3 | - |
| | CNC-3 axis for turning and milling | - | - | - | - | - | - | - | - | 1 |
| | Welding Machine (any type) | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | - |
| | Electric metal cutter | 1 | - | 2 | 2 | 2 | 1 | 2 | 1 | - |
| | Electric metal grinder | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | - |
| | Electric metal profiler | 1 | - | - | 1 | - | - | 2 | - | - |
| 3 | **Detailed Support Equipment** | | | | | | | | | |
| | Hoist/Pulley | - | - | - | - | - | - | - | - | - |
| | Spirit level | 2 | 2 | 2 | 2 | 2 | 1 | 5 | 2 | 1 |
| | Electric metal polisher | 3 | 2 | 1 | 4 | 1 | 1 | 6 | 2 | - |
| | Trestle | 2 | 3 | 1 | - | 2 | 1 | 5 | 3 | - |
| | Grippers/clamps/lanyard | - | 2 | 2 | 5 | 3 | - | 4 | 3 | - |
| 4 | **Other Equipment** | | | | | | | | | |
| | Jig – any type | 2 | 3 | 1 | 3 | - | 2 | 4 | 3 | 3 |
| | Roller – any type | 2 | - | - | 1 | - | - | 2 | 1 | - |
| | Set of tools (screwdriver - all types & sizes) | 5 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 4 |
| | Reamer | - | 1 | - | - | 1 | 1 | 2 | 2 | - |
| | Handy drill - any type | - | 1 | - | - | 1 | 1 | 3 | 3 | - |
| | Moulder - any type | - | - | - | - | - | - | - | - | - |
| | Scrap milling machine | - | - | - | - | - | - | 1 | 1 | - |

*W=Workshop, I=Institution, L=Laboratory;
**DJ=Dinamika Jaya, Bk=Berkah, Ar=Aris, CM=Citra Mandiri, Kr=Karunia, An=Aneka, BLK=Balai Latihan Kerja, PU=Production Unila, CU= CNC Unila.

In terms of matching the equipment of the facilities to the set of desirable equipment for participation in the PKM program, Tab.1 illustrates, that all nine facilities have at least one main production machine that can benefit the PKM program and all but the CNC Laboratory have the desirable support tools. There is a wide variation in the size of the workshops from Aneka, which has 3 main production machines and 6 workers to Berkah, which has 10 main production machines and over 50 workers. The facility with the greatest number of main production machines and support tools was the BLK training centre. The Production Laboratory has the third highest number of main production machines but had only been operational for 4 years (at the time of the survey) with only 2 workers.

Tab.1 also depicts the way that the main production machines and support tool are distributed across the facilities. Six main production machines and five types of support equipment had been established a forming a list of desirable equipment as mentioned previously. During the survey of the facilities, additional types of tools were noted as having the potential to support the PKM program and these tools were classified under the heading of “Other Equipment” and outlined in the table. In terms of main production machines, Table 1 shows that most labs have welders, cutters and grinders. Only 5 of the 9 facilities, however, have a lathe, which is important in terms of machining 3 out of the 4 component groups of the PKM e.g. tower, transmission and pump In addition only one third of the facilities have a metal profiler, used for making the blades of the PKM. As a result only Dinamika Jaya and BLK have the equipment required to manufacturer/repair all the component groups of the PKM design, and even these facilities are not equipped for high precision CNC machining As expected the only facility to have a CNC machine is the CNC laboratory at the University of Lampung. The consequence of this is that any PKM part that requires high precision machining would have to be sent to Bandar Lampung. If this is not possible then the part would have to be either sent to the CNC laboratories in Jakarta or imported from overseas. In the interests of having a locally made product, the CNC in the Bandar Lampung would be preferred but it needs to be kept in mind that this facility is out of the MTB subdistrict, has only 1 worker and potentially could cause a bottleneck in the PKM production/repair process. In terms of support equipment, the key point to note is that none of the facilities has a hoist/pulley. The consequence of this is that more labourers would have to be assigned to carry out the tasks of assembly of the PKM component groups e.g. the tower and transmission systems.

## Survey Part C

Tab.2 shows the responses to Part C of the survey. It is observed that there are several weaknesses in the operational management aspects of the facilities. This includes a lack of attention to training programs for the community of Lampung people and a lack of accredited training programs in general. It is observed that only BLK, Production and CNC laboratories provide general training for the local community. Several workshops only provide on site training to those with an educational background related to metal working (e.g. welding, cutting and profiling using a milling machine). Other weaknesses that have been identified in the operation of the facilities are a lack of quality assurance of equipment supplied by non-permanent suppliers and a lack of certification approval for equipment calibration procedures. These conditions indicate a potentially serious problem for the reliability and sustainability criteria associated with the PKM program.

Tab.2. Part C Survey questions related to the operation of the facilities

| No. | Question | Yes | No |
|---|---|---|---|
| 1 | Do you have training programs (either comprehensive or non-comprehensive)? | 3 | 6 |
| 2 | Do you have a permanent supplier(s) of the training materials and spare parts? | 2 | 7 |
| 3 | Do you have a training program for educators? | 8 | 1 |
| 4 | Does your training program have accreditation or certification? | 1 | 8 |
| 5 | Do you have a regular equipment calibration program? | 1 | 8 |

### Survey Part D

Interviews with facility managers were semi-structured, loosely based around a set of typical questions focussing on future plans for the facilities in the areas of: (1) membership of professional associations in the area of metal working and forming; (2) certification in the area of workshop/laboratory management; (3) operation and administration procedures; (4) safety procedures in manufacturing; and (5) storage and inventory systems.

The interviews indicated that only 4 of the facilities had current membership of a professional association, examples of which included manufacturing, welding, industrial machinery and training associations. 7 of the facilities believed that becoming members of a professional association would be advantageous for the facility. None of the facilities were certified in terms of the quality of the management system. It was noted that, although 5 of the facilities planned to obtain certification, only 2 of the facilities had made any efforts in the direction of certification such as document preparation and reconfiguration of their production line.

To improve their operation and administration procedures, 6 of the facilities had made several fundamental changes, namely: (1) publishing more manuals for tool and manufacturing safety procedures; (2) marking a safety line in the manufacturing line; (3) printing work flowcharts and (4) providing log books. These six facilities stated that the improvements that they had introduced had brought many benefits to the facility. Specific safety procedures in manufacturing are associated with correct machine procedure (including the general cleaning procedure of the machining area) and use of safety devices/tools. The problems of implementing safety procedures were discussed by the managers during the interviews including the risk of high cost of investment in technology without guarantee, loss of customers due to the additional cost attached to the product; and the cost of training employees.

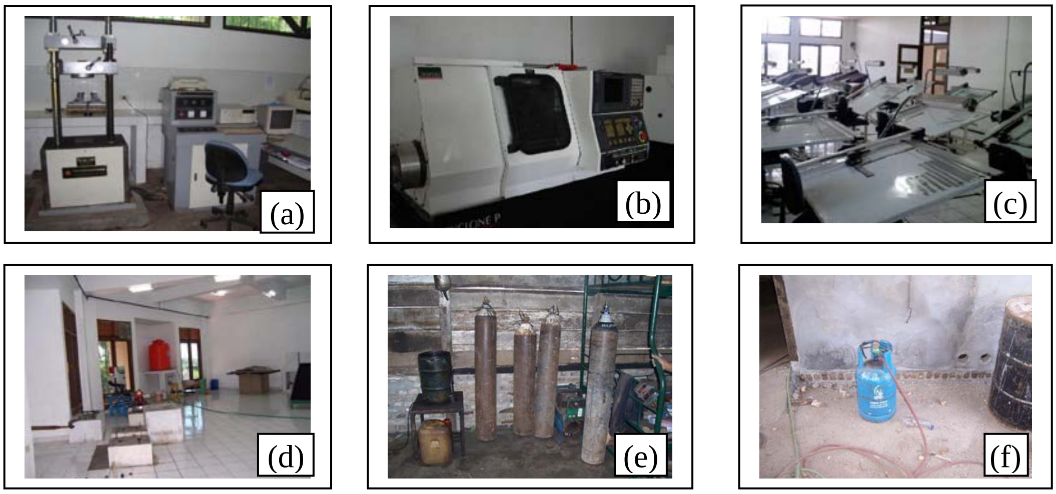


Fig.2. Photos of amenities available in the Production and CNC laboratories of Lampung University: (a) Material testing machines; (b) CNC lathe machine; (c) drawing class-room and (d) available space or room for in-class training activities. Photos of improvement for the Aneka workshop:(e) previously gas welding was conducted in a closed area with a wooden wall; (f) gas welding is now conducted in an open area with a brick-layered wall.

For small-medium enterprises e.g. the workshops, good storage and inventory systems are very difficult to achieve since limited area is allocated to a storeroom. Most workshops provide a small area near the manufacturing area, which also compromises the safety of operations. The results of the interviews indicated that only 2 of the workshops have been organised to the extent of obtaining inventory certification from the relevant bodies or agencies. Photographs were taken of each of the facilities to document their conditions, safety issues and general operation. The best conditions were observed in the BLK and the Production and CNC laboratories of Lampung University while there was gradual improvement in conditions for some of the workshops. Fig.2 shows the range of amenities in the laboratories at Lampung University as well as an example of safety improvements for the Aneka workshop.

## ANALYSIS AND DISCUSSION

Each facility has it own advantages and disadvantages. Naturally those facilities that have the equipment to manufacture all the component groups of the PKM e.g. Dinamika Jaya and BLT have strong advantages but there are other factors involved. For example using a combination of two facilities that together contain the complete set of desirable equipment, can provide training and are close to the installation site may be preferable to having one facility that contains all the desirable equipment but without trained staff or good management practice. In order to interpret the results and assess each facility for its suitability for providing technical support to the PKM program, it is necessary to adopt a ranking system for the facilities. To do this a set of key criteria, related to the provision of technical support for the PKM program, are established and then each facility is ranked against this set of criteria.

The authors established a ranking system using five main criteria and twelve sub-criteria. The criteria are defined in terms of location for the workshops (Location), values of services (Values), capacity to produce and repair (Capacity), ability to provide training and installation for villagers (Training) and competencies in compliance with regulations and quality management (Competency). Sub-criteria are given weighting factors (e.g. $\alpha_1$, $\alpha_2$, $\alpha_3$…, etc.) to grade the criterion. Criteria are given weighting factors (e.g. $\alpha$) to provide an overall grade. Tab. 3 shows the result of applying the ranking system to the 9 facilities.

For the location criterion, it is observed that three sub-criteria play a significant role, namely: distance from the site; accessibility to the site and security of the workshop. These sub-criteria affect installation, operation and maintenance costs. In the case of the PKM pilot project, the distance of Tanjung Menang from the University of Lampung (where the demonstration PKM was produced) doubled the transportation cost during pre-installation (Yudiantoro B 2006).

For the criterion of value of service, there are various factors that contribute to the time and cost of the service. For instance, different facilities have different types of transport vehicles, which can be used to deliver PKM components and to provide maintenance services for the PKM. The Dinamika Jaya workshop, for example, has its own vehicle but a less experienced welder than the Berkah workshop, which uses a rental vehicle. In addition, if the facility also has others jobs from other customers to process at the same time, the PKM job may be postponed for several days and the time required for the service will be increased. These types of factors contribute to significant variations in terms of time and cost for services.

The important factors in a facility's ability to provide training related to the installation and maintenance of the PKM has been determined as having the required educational background as well as the time and space to run the training. The capacity and competency are the most important criteria for the facility. In this analysis, expertise, labour and equipment-materials have been defined as sub-criteria for the capacity criterion. For the competency criterion, degree of compliance with standards and degree of care and precision have been selected as sub-criteria.

Tab. 3. Result of ranking facilities for technical support to the PKM program

| No. | Criteria & Sub-criteria | Code | Workshops** DJ | Bk | Ar | CM | Kr | An | BLK | PU | CU |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Location | α | 7.4 | 7.4 | 6 | 6 | 6.2 | 6.8 | 6.2 | 5 | 5 |
| 2 | Value | β | 8 | 8 | 6.2 | 6.2 | 8 | 5.6 | 6 | 6.4 | 6.4 |
| 3 | Capacity | γ | 8 | 7.2 | 4.6 | 5.7 | 5.5 | 4.3 | 6.5 | 6.5 | 4.9 |
| 4 | Training | δ | 6 | 6 | 3.4 | 4 | 5.4 | 6 | 8 | 8 | 8 |
| 5 | Competencies | ε | 6 | 6 | 4 | 4 | 6 | 6 | 8 | 8 | 8 |
| **Total score** | | | **7.18** | **6.94** | **4.85** | **5.24** | **6.13** | **5.59** | **6.89** | **6.71** | **6.23** |

**DJ=Dinamika Jaya, Bk=Berkah, Ar=Aris, CM=Citra Mandiri, Kr=Karunia, An=Aneka, BLK=Balai Latihan Kerja, PU=Production Unila, CU= CNC Unila.

The analysis shows that there is a group of 4 facilities which clearly rank higher than the other facilities in terms of suitability to provide technical support for the PKM program. These are the Dinamika Jaya and Berkah workshops, the BLK Institute and Production Unila. Tab. 1 shows, however, that Production Unila has a limited number of workers but could possibly be integrated in a program with one or more of the other 3 facilities in a training (as opposed to production) role. The CNC laboratory ranked fairly low and thus would not be considered to have a major role in the PKM program but it is likely that other workshops will have to sub-contracting work to the CNC laboratory if high precision machining was required as previously discussed.

## CONCLUSION AND RECOMMENDATIONS

A survey of technical support has been carried out in order to assess the viability of a widespread deployment of locally-made capillary wind pumps (PKMs) in the Mesuji-Tulang Bawang (MTB) subdistrict of Lampung, Indonesia. Ten facilities in the region of the MTB were selected for the survey on the basis of their general experience in metal working and metal forming. A list of desirable equipment for a facility was constructed by assessing the types of main production machines and support equipment that would be required in the event of failure of the various PKM components. The survey was given to managers of technical facilities such as laboratories and workshops and consists of four parts with Parts A to C in the form of written questionnaires and Part D as a semi-structured interview. Ten facilities were selected to participate in the survey on the basis of having sufficient quality in the general area of metal forming & manufacturing.

The response rate for the survey was 90% and the results of Part A and B showed that many of the nine respondents contained the desirable equipment although a number of facilities were lacking lathes, which play a crucial role in the manufacture/repair of 3 out of the 4 component groups of the PKM, and metal profilers, which play a crucial role in blade production. In addition, only one facility had a CNC machine, which would be required for any high precision machining of parts for the PKM. The results of Part C showed that the workshops do not have accredited training programs, adequate calibration procedures and regular suppliers. The average workshop does not have any assistance to set up inventory procedures to the relevant standards. In terms of work safety, the problems in implementing and sustaining work safety standards can be defined in terms of the cost for additional safety tools and the risk of loss of customers associated with the increase prices associated with implementing safety standards. The YPC plans to address some of these issues by campaigning for education for the facilities in the area of operation and management, links to relevant standards agencies and a price protection program of raw materials. In addition, Part D of the survey indicated that workshop managers are planning to target three priority areas for improvement: inventory procedures, work safety standards and efficiency of operation.

The survey results were analysed to assess each facility for its suitability for providing technical support to the PKM project. This involved establishing the key criteria for provision of technical support and ranking each facility against this set of criteria. It is shown that there are 4 recommended facilities for providing support to the PKM program: the Dinamika Jaya and Berkah workshops and the BLK Institute, with the Production Laboratory of the University of Lampung in a training role.

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## BRIEF BIOGRAPHY OF PRESENTERS

**Mr. Ahmad Taufik** is a PhD student at the School of Engineering and Energy, Murdoch University. He is also an activist as well as a principal researcher of a NGO in Indonesia dealing with renewable energy, named Pijar Cendikiawan Foundation. Since 2001, he has been doing several research studies in the areas of renewable energy and conservation energy for developing country, particularly Indonesia.

**Dr. Jonathan Whale** has worked in the area of renewable energy in the UK, USA and Australia over the last 18 years including periods working on projects with the International Energy Agency (IEA), the US National Renewable Energy Laboratory (NREL) and the Research Institute for Sustainable Energy (RISE). He is currently Director of the National Small Wind Turbine Centre at RISE and a Lecturer in Energy Studies and Renewable Energy Engineering at Murdoch University in Perth. Dr Whale has research interests in the area of small wind turbines, sustainable development and energy efficiency. He has authored or co-authored a total of 22 publications together with 20 commercial-in-confidence reports.