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Technology choice

An integrated approach for the choice of appropriate technology

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Firms are often faced with problems related to choice of technology. An approach to decision-making is suggested which integrates the salient and valuable features of both techno-economic and contingency approaches. It is based on the findings of innovation diffusion research and the ideas of appropriate technology. It suggests three categories of criteria for screening: techno-economic, organisational and operating domain compatibility. The choice of technology could be based on the results obtained by this screening process. The approach is illustrated with a 2.5MW wood waste power plant technology.

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FROM A BUSINESS perspective, the term 'choice' refers to a very strategic action that can significantly influence the long-term sustainable development of a firm. From a management of technology perspective, firms are usually confronted with many problems related to choice: choice of technology; technique; mode of technology acquisition; R&D projects; product and/or service mix; and markets and market segments. In general, it may be said that management of business activities almost always involves the handling of choice-related issues and problems.

Of all the technology-related choice problems, the issue of choice of technology began to assume considerable importance in the late 70s in both the developed and developing countries. In the industrialised developed countries this was because of a convergence of a wide variety of concerns including the need to:

- find a more harmonious and sustainable relationship with the environment;
- identify a way out of the accelerating energy and resource crises;
- reduce alienating work;
- develop more socially conducive work places; and
- revitalise local culture to counter the increasingly homogeneous and sterile mass culture propagated through the electronic media.

On the other hand, the issue of technology choice gained importance in developing countries for a different set of concerns. The most prominent was the recognition that imitating industrialisation

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strategies adopted by developed countries had not been successful in solving the problems of poverty and inequality.

There are many reasons for this. The world's technological resources, which are the necessary base for industrialisation, are essentially controlled by the most advanced nations, and have been primarily developed to serve their economies, factor costs and consumer life-styles. The commercial interests of these nations have had a dominant effect on the industrialisation process in developing countries.

Technology transfer mainly served business interests in utilising: natural resources without any concern for environmental issues; cheap labour; and élite consumer markets. The result, for hundreds of millions of people, had been the modernisation of poverty and, in many cases, the introduction of imported technologies had resulted in a fundamental and massive assault on local culture. Therefore, the issue of technological choice arose essentially as an effort to import technology, adapt it if necessary, and develop technologies appropriate for the surroundings and compatible with the resource endowments.

These efforts also led to the coining of many terms such as "intermediate technology" by Schumacher,[1] "appropriate technology" by Morawetz,[2] "progressive technology" by Marsden,[3] "third world technology" by Mathur,[4] "alternative technology" by Dickson,[5] as well as 'grass roots technology', 'kind technology', 'barefoot technology', 'evolutionary technology', 'non-violent technology', 'non-polluting technology', 'soft technology', 'indigenous technology', 'self-help technology' and 'green technology'. The proliferation of such terms, each coined to deal with very specific orientations of the analysts, appears to have caused considerable confusion.

This has led to inappropriate technology choices in many cases, because the specific orientations introduced by these analysts to examine special issues tend to be rather loosely applied without examining their relevance in the particular situation. Bowonder[6] has summarised the major reasons given by several analysts identifying the constraints that adversely affect the choice of appropriate technologies. Even though these views were expressed by the analysts over a decade ago, the reasons appear to be more relevant today, especially in a developing country context. From a technological choice perspective these reasons may be elaborated as follows:

- The absence of formalised and institutionalised criteria which lead to exclusive or monocular dimensions being used in selecting technologies.[7]
- The predominance of exogenous planners in technology selection and, in general, their inability to "extend the field of vision".[8]
- Lack of co-ordination by different planning entities, and their inability to reach a consensus on the criteria to be used, and their prioritisation, in the choice of appropriate technologies.
- The inability of many developing country firms to comprehend future complexities, and their restricted field of perception that makes it difficult for them to project their aspirations into the future.[9]
- The influence of misconstrued socio-political paradigms in establishing technology-choice criteria — the misinterpretation of 'self-sufficiency' for 'self-reliance', for instance.
- The non-availability of 'clean information' to many developing country firms for taking technology-choice decisions. Due to their lack of skill in collecting relevant data and analysing it independently, many firms base their decisions on 'edited' information form potential technology suppliers which often tends to stress only the main message that the provider of such information seeks to convey.

All these limitations tend to work in a synergistic manner in weakening the technology-choice process: as a result, technology that is not appropriate is often selected. Thus, in making technology-choice decisions, developing country decision-makers need to:

- develop multi-faceted perceptions that will incorporate not only pure techno-economic criteria but also other, perhaps even more critical, dimensions relevant to a particular setting;[10]
- encourage interdisciplinary interactions to facilitate co-ordination among planning entities and to reach a consensus on needs assessments and their prioritisation;[11] and
- use "multiple perspectives" in decision-making to extend the "field of vision".[12]

Any approach that is intended to facilitate technology-choice decisions needs to incorporate these aspects and must guard against being unduly influenced by the very narrow appropriate technology orientations that have been introduced in the past. This paper is an attempt to provide such an integrated approach.

In order to identify criteria that could examine such multiple perspectives, the paper firstly investigates the various measures that have been proposed by analysts in determining appropriateness and suitability of a technology for a specific purpose. These criteria are then presented in an integrated manner for easy application in making technology-choice decisions. The approach is then illustrated using the example of a biomass energy technology. Concluding remarks on the application and possible extensions of the proposed approach are then made.

One of the critical steps in the choice of a technology is to establish a set of acceptable and usable predetermined criteria which can be used to evaluate candidate technologies

Factors in technology choice

Making decisions regarding the choice of technology has basically taken two approaches, which for explanatory purposes may be called the 'pure techno-economic approach' and the 'contingency approach'.

The pure techno-economic approach advocates the choice of technology based on technical criteria and well established economic analytical procedures such as cost-benefit analysis. This approach usually leads to the selection of a technology which satisfies all the stipulated technical criteria and promises the highest economic efficiency or highest net benefit.[13,14] This is useful when the chosen technology is to be utilised in surroundings similar to the one in which it was developed and successfully commercialised, and for similar purposes. However, when the surroundings of the potential adopter of the technology and the objective functions differ, the pure techno-economic approach needs to be modified.

Analysts such as Dahlman and Westphal,[15] Fransman[16] and Sharif[17] have thus advocated the incorporation of other factors such as the technological capability of the potential user, nature of the supportive infrastructure and raw material availability. This contingency approach, they argue, is more suitable for firms in many developing countries.

However, the use of either of these two approaches requires the evaluation of the candidate technologies in relation to some predetermined criteria. Analysts have sometimes been accused of using criteria that favour the selection of technologies that they prefer. Others argue that the criteria used do not adequately reflect the concerns highlighted by the techno-economic and contingency approaches.

Thus, one of the critical steps in the choice of a technology is to establish a set of acceptable and usable predetermined criteria which can be used to evaluate candidate technologies. The literature on 'appropriate technology' and 'diffusion of innovations' is rich in such criteria, some of which will be outlined below.

Appropriate technology

Technology is a result of R&D efforts. However, different R&D efforts at different places produce different technologies for achieving the same or similar goals. This is because the operating domain (determined by parameters such as population, resources, economic, technological, environmental, socio-cultural and politico-legal systems) which acts as a guiding force for the production of technology, is different even though the driving force, exerted by various needs, may be the same.

Moreover, the objective function used in the development of technology at different places could also vary. Two basic components of the objective function are maximisation of opportunities (positive effects) and minimisation of losses (negative effects).

Therefore, any technology is 'appropriate', at the time of development, with respect to the operating domain for which it has been developed, and in accordance with the objective function used for development. It may or may not be appropriate at the same place at a different time, because the operating domain and/or the objective function may have changed. Similarly, it may or may not be appropriate at a different place at the same time or at different times, because the operating domain and objective functions may be similar or different.

Thus, technological appropriateness is not an intrinsic quality of any technology, but is derived from the operating domain in which it is to be utilised and also from the objective function used for evaluation. It is, in addition, a value judgement of those involved.

According to this simple conceptual framework, any technology is appropriate at the time and place of original application. It is still appropriate at a later time and/or at a different place if the operating domain and the objectives are similar to the original ones. It is not appropriate at a later time and/or at a different place for three possible reasons:

- different or changed operating domain;
- different or changed objectives; and
- different or changed operating domain and objectives.

The simple examples of the chemical pesticide DDT, and coal-based technology for power generation provided by Sharif[18] illustrate this thinking. DDT, which was once appropriate, is now banned by many industrialised, developed countries because of its negative impact on the environment. On the contrary, coal-based power generation technology which was once given up due to more attractive oil-based technologies, and its 'dirtiness', has now become appropriate with the fear of oil shortages.

These examples serve to stress that technological appropriateness needs to be explained with reference not only to the intrinsic properties of the technology but also to the operating domain, as viewed by those involved. Based on these consider-

Table 1. Criteria for selecting appropriate technology

Criteria	Preferred path
Energy intensiveness	Should use less energy
Labour intensiveness	Should be in accordance with the manpower endowment of the country but without leading to inefficiency
Cost intensiveness	Affordable
Productivity	High
Durability	Easy to maintain
Ease of operation	Easy to impart operation and maintenance skills
Scale of operation	Suitable for the use of small- and medium-scale units
Sectoral effectiveness	Capable of contributing to more than one economic sector such as (power, agriculture, forestry, industry etc)
Raw material requirements	Ability to use locally available raw material
Import substitution	Utilising local resources
Ecological stability	Environmentally friendly
Waste recycling	Capable of utilising waste
Rural orientation	Suitable for use in rural areas
Delocalisation	Capable of being diffused into many localities
Income disparity reduction	Capable of reducing income disparity
Socio-cultural stabilisation	Should not have an adverse impact on socio-cultural conditions
Local ownership	Capable of facilitating local ownership

ations, Bowonder[19] has proposed a set of choice criteria that may be used to decide the appropriateness of a technology. Similar criteria have also been recommended by UNIDO.[20] These criteria with suitable adaptations are listed in Table 1.

Diffusion of innovations

The term innovation is used broadly in the field of management of technology to refer to a new product, technique, practice or idea. The term 'new' is also used in a fairly general sense to reflect the fact that an item classified as an innovation might be intrinsically new or it might only be new to the setting in which one finds it. A well accepted definition by Lin and Zaltmann[21] of innovation is "any idea, practice or material artifact perceived to be new by the relevant unit of adoption". Thus technologies of relevance to firms are included under this broad definition.

Considerable work from multi-dimensional viewpoints has been carried out in diffusion of innovations over the last few decades. A comprehensive review of such work has been outlined in Ramanathan.[22] Summaries are also available in Sharif and Ramanathan.[23-25] This extensive literature on the diffusion of innovations shows that adoption decisions are taken by potential users, especially at the firm level, based on a number of demand and supply side criteria.

Demand side factors include:

- Profitability of the investment in an innovation;[26,27]
- Size of the investment required to adopt the innovation;[28-30]
- Utility-adjusted price ratio between the innovation and its competitors;[31]
- Technological complexity of the innovation;[32,33]
- Age, condition, and rate of obsolescence of the existing capital equipment that an innovation seeks to displace;[34-36]
- Quality characteristics of the innovation;[37,38]
- Type of interaction of the innovation with other concurrent innovations (independent, complementary, contingent or substitute);[39]
- The number who have already adopted and not yet adopted the innovation;[40-51];
- The social, psychological, economic and locational characteristics of those potential adopters;[52-54]

Supply side factors include:

- Supplier actions pertaining to market selection, market segmentation, promotional communications, pricing and infrastructure development (after-sales service, spare parts supply, trouble shooting and so on);[55-58] and
- Actions of related private and public organisations such as infrastructure development, promotional communication and regulation/promotion of the innovation.[59-61]

Thus it appears that, when developing criteria for the choice of a technology, it may be useful to incorporate the criteria suggested by both diffusion of innovation and appropriate technology literature in an integrated manner. The next section presents an integrated approach for technology choice.

An integrated approach

When the criteria outlined above are examined it appears that basically they attempt to assess whether a particular technology or innovation: meets the desired techno-economic specifications; is compatible with the economic and technological capability attributes of the organisation where it is to be used; and is compatible with the expectations of the operating domain — the national socio-political milieu. These three categories of criteria, for the sake of convenience and ease of explanation, may be referred to as: techno-economic compatibility criteria (TECC); organisational capability compatibility criteria (OCCC); and operating domain compatibility criteria (ODCC).

The criteria attempt to assess whether a technology meets the desired techno-economic specifications, and is compatible with both the economic and technological capability attributes of the user, and the expectations of the national socio-political milieu

Table 2 shows a synthesis of the various criteria under each of these three categories. While the proposed integrated approach may appear similar to the contingency approach already described, the essential difference is that it goes a step further by specifying the criteria to be used in technology choice rather than merely highlighting the need for a contingency approach. It is envisaged that the use of the integrated approach would facilitate the operationalisation of the contingency approach.

The TECC, OCCC and ODCC can be applied to the problem of technological choice in two ways. Firstly, the criteria can be uniformly applied to the candidate technologies, and their performance or rating with respect to each criterion can be obtained. Using methods such as those developed by Saaty[62] and Souder[63], for handling multiple criteria decision-making situations, the "most appropriate" or "best" technology can be selected from among the alternatives.

Secondly, even if only a single technology comes up for evaluation, it can still be rated *vis-à-vis* these criteria with a view to identifying its strengths and weaknesses in terms of its compatibility from techno-economic, organisational capability and operating domain compatibility points of view. It is possible that in some situations the weaknesses can be rectified through appropriate technological, managerial or policy interventions.

The proposed integrated approach could thus provide a useful analytical framework for handling the problem of technological choice. The salient features of this approach are now illustrated, albeit in a restricted manner, using an example from biomass technology.

Table 2. Proposed technology choice criteria

Criteria	Evaluation attributes
Techno-economic compatibility criteria (TECC)	
Technological complexity	Degree of ease of use
Quality characteristics	Degree of contribution towards the improvement of the quality of output
Energy intensity	Degree of energy saving
Ecological stability	Degree of environmental friendliness
Waste recycling	Degree of usage of waste and facilitation of pollution prevention
Cost	Size of investment required
Profitability	Degree of enhancement of profitability
Utility-adjusted price ratio	Comparison with other alternative technologies
Productivity	Extent of productivity increase
Demonstrated usefulness	Number of firms already using the technology
Organisational capability compatibility criteria (OCCC)	
Scale of operation	Suitability for the use of small and medium firms
Labour intensity	Degree of use of available labour and skills
Durability	Degree of ease of maintenance
Ease of operation	Degree of ease of operation
State-of-the-art	State-of-the-art of the technology in comparison to technology existing in the firm
Interaction	The type of interaction that the technology will have with other concurrent technologies currently being used by the organisation — independent, complementary, contingent or substitute
Operating domain compatibility criteria (ODCC)	
Supplier actions	Degree of facilitation by supplier in terms of market selection, market segmentation, promotional communications, pricing and infrastructure development (after sales service, spare parts supply, troubleshooting etc)
Government actions	Degree of facilitation by the government in terms of infrastructure development, promotional communication and regulation/promotion (fiscal and financial incentves etc)
Sectoral effectiveness	Degree of contribution to other economic sectors
Raw material requirements	Degree of use of locally available raw materials
Import substitution	Degree of conservation of foreign exchange
Rural orientation	Suitability for use in a rural setting
Delocalisation	Capability of being diffused into many localities
Income disparity reduction	Degree of contribution towards reducing income disparity
Socio-cultural stabilisation	Degree of non-adverse impact on socio-cultural conditions
Local ownership	Degree of facilitation of local ownership

ASSESSING A BIOMASS POWER PLANT

As an illustrative example, the appropriateness of a 2.5MW wood wastes power plant will be analysed using the integrated approach. The example is based on the information found in reports published by the ASEAN-EC Cogen Programme.[64-66] The analysis is presented in five parts: the first gives background information related to the relevance of wood wastes power plant technology (WWPPT); the next three deal with the application of the three categories of criteria — TECC, OCCC and ODCC to the technology; and the last part presents some observations regarding this technology. All economic and technical information quoted in the analysis are taken from the ASEAN-EC Cogen Programme reports.

Overview of technology

The Association of South East Asian Nations (ASEAN) comprising Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, and Thailand is currently enjoying the largest economic growth rate in the world, resulting in an ever-increasing demand for energy and infrastructure. With the exception of Brunei and Singapore, the demand for energy is expected to surpass the supply. As a result, the governments of these nations are currently in the process of implementing various programmes to increase the supply of energy through both traditional and alternative sources. To limit public-sector capital requirements for infrastructure, and to prevent accumulation of foreign debt, the ASEAN nations are actively seeking private-sector participation in power generation.

In this context, power generation through biomass energy technology has received considerable attention. With the exception of Brunei and Singapore, the ASEAN countries produce large amounts of agricultural products such as rice, sugar-cane, palm oil, coconut and rubber. In addition, Indonesia and Malaysia are major processed-wood exporters.

These agro-based industries generate huge biomass residues, which have been estimated to have the energy equivalent of 25 million tons of oil equivalent (TOE) per annum. It is estimated that only about 50% of these residues is used for heat or power generation, and generally with low efficiency, since there is no demand for autoproduced energy in excess of the agro-industrial firms' own needs.

However, with the recent emphasis by the ASEAN governments on seeking private-sector participation in electrical power generation, and improved access for autoproduced electricity to national grids, generation of electricity from biomass and supplying the surplus to the national grid could become economically attractive to certain classes of agro-based firms.

Most of the wood industries (sawmills, plywood factories, and furniture factories) in the ASEAN are located in Indonesia and Malaysia. They produce considerable amounts of wood wastes. For instance, in Malaysia, it is said that about 7.4 million cubic meters of wood residue are produced annually representing an energy potential of about one million TOE.

These residues are often not used and pose a great disposal problem. At present in many instances the wastes are burnt in an incinerator, used as landfills, or simply dumped in rivers. The method of incineration is often not environmentally friendly and causes considerable air pollution. What is also unfortunate is that the wood wastes which can be used as a fuel are simply destroyed without any form of energy recovery. At the moment only the biggest and most modernised of these wood industries use waste wood to cogenerate heat and power. The others are grid connected or simply use diesel generator sets.

Table 3. Process components for the 2.5MW wood wastes power plant

System component	Specifications
Wood chipper	30 m^3/h
Chips conveyor	
Silo and discharging system	240 m^3
Conveyor	
Fuel distribution and measuring unit	15 m^3
Automatic feeding system	5 levels
Combustion furnace	
Steam boiler	
capacity	19t/h
working pressure (superheated at 300°C)	30 bars
design pressure	33 bars
Superheater	
Deduster	150 mg/Nm^3 (1%ash)
Steam turbine (multistage steam turbine suitable to drive a generator	
specific steam consumption	7.35 kg/kw_e
initial steam pressure	30 bars
exhaust steam pressure	0.35 bars
Generator	2,500 kw
Condenser	19,000 kg/h of steam
Cooling tower	600 m^3/h
High-tension switchgear, control panel and automatic regulation	
Chimney	

The proposed 2.5MW power plant is intended to generate electricity for the use of a timber complex by burning the resultant wood wastes. The components of the wood waste power plant are shown in Table 3.

Application of TECC

Using information from the ASEAN-EC Cogen Programme Reports[64,66] and Girard,[65] an assessment of the proposed WWPPT using the TECC will be carried out.

Technological complexity

It appears that WWPPT is not difficult to use. Timber complexes often use boilers which may be low pressure steam boilers or hot water boilers. Thus, with some short-term training of operatives and engineers, the capability to operate WWPPT can be developed. Such training could be provided by the supplier of WWPPT.

However, there are three complicating factors with respect to the use of biomass-based power generation technologies. First, in WWPPT, the boiler will be bigger than conventional oil-fired boilers for the same output. This is because wood waste is bulky and is a low energy content product. Thus the engineering costs associated with purchasing and installing WWPPT are usually higher than conventional oil-fired power plants.

Secondly, due to its bulkiness, storage of wood wastes requires considerable space. This increases storage space requirements and consequently storage costs.

Thirdly, since wood waste differs with regard to shape, size, moisture content and so on, the raw material needs to be prepared before being used to fire the boiler. The preparation may involve processes such as drying, chipping, cutting, milling, mixing and compacting. These supplementary activities also increase engineering costs and space required.

Thus, while the use of WWPPT itself is not complex, its installation and maintenance tend to be more complicated than the use of conventional oil-fired power generation technology or the use of diesel generators.

Quality characteristics

This criterion is not relevant in the current assessment because there is no information to indicate that the use of WWPPT will improve the quality of the timber products. However, this criterion will be critical when process technologies are being evaluated.

Energy intensity

The use of WWPPT reduces the use of fossil fuels. It is expected that the proposed plant will save approximately 4,950 to 5,560 tons of diesel per annum which may otherwise have to be used to generate electricity through the use of a generator.

Ecological stability

Girard[65] points out that the equivalent tons of carbon dioxide (CO_2) emitted per TOE of energy generated after clean burning by different technologies are:

Coal	1.0
Oil	0.8
Gas	0.6
Wood	0.3
Biomass energy residues	0.3

The use of WWPPT and biomass for power generation could be said to have a beneficial impact on the environment. It has even been pointed out that the CO_2 generated by using biomass as energy sources will be removed later through photosynthesis by growing crops and trees. In addition, since biomass does not, in general, contain sulphur, there is no toxic and environmentally degrading sulphur dioxide SO_2 produced.

Ecologically the use of biomass for power generation could be said to have a beneficial impact on the environment because of the low carbon dioxide emission: that which is released will be removed later through photosynthesis of plants

The use of WWPPT thus has beneficial impacts on the environment because it helps to:

- avoid river pollution caused by dumping of wood wastes into the rivers;
- reduce the high pollutant exhausts caused by inefficient incinerators; and
- reduce the CO_2 (carbon dioxide) and SO_2 (sulphur dioxide) emissions normally caused by the use of diesel generators used as an alternative for electricity generation.

Waste recycling

WWPPT uses waste produced by timber complexes thereby also reinforcing the beneficial impacts on the environment. The different types of wood wastes that can be used by WWPPT are: sawmill wastes (wet sawdust and wet off-cuts); fabrication wastes (dry moulding dowels); and plywood wastes (wet log ends, wet log core and veneer, dry side cuttings, dry sawdust and dry veneers). At present over 50% of the wood wastes generated in Malaysia and Indonesia are either incinerated, used as landfill or dumped into rivers.

Cost

At 1991 prices the various costs in ECU (European currency unit) for the 2.5MW WWPPT were:

Total capital costs	=	3,125,821
Annual fixed costs		
labour costs	=	52,898
annual maintenance costs	=	85,460
utilities	=	46,000
Variable costs		
fuel costs	=	0
lubricants and water treatment	=	300

These costs can be compared with the costs of alternative technologies.

Profitability

At 1991 prices the various financial benefits to be gained per annum through the use of WWPPT were:

Electrical energy cost saving (at 100% load factor)	=	904,241 ECU
Wood waste disposal savings	=	158,818 ECU

However, costs will be incurred, as mentioned above, due to the investment in WWPPT and the cost of operating it. The net financial benefits will have to be worked out in relation to other options being studied. Profitability can be further enhanced if the excess power generated can be sold to other buyers or to the national grid. This is now possible because most of the ASEAN governments are currently implementing policies to encourage private sector involvement in power production through cogeneration.

Utility-adjusted price ratios

This is difficult to estimate because an accepted surrogate for utility will have to be arrived at first. However, measures such as internal rates of return and/or payback periods could be used to compare the performance of WWPPT with alternative technologies. It may be necessary to use sensitivity analysis (which would involve using different discount rates, load factors, adjustments for inflation and so on) to get a better picture.

One of the greatest benefits of using WWPPT for electrical power generation is that it tends to reduce the dependence on unreliable power supply from the national grid, such as in the Philippines. This aspect of higher utility due to increased reliability in terms of the supply of a critical production input, and prevention of lost production is often not considered in project feasibility studies.

Productivity

The productivity of WWPPT in relation to the cost of purchasing electricity from the national grid may be assessed by comparing the cost of electricity generated using this technology (in Malaysian dollars/kwh based on 1991 prices).

Using WWPPT (100% load factor, 10% discount rate)	=	0.1017
Using WWPPT (75% load factor, 10% discount rate)	=	0.1441
Sarawak Electricity Supply Corporation charges (an additional load demand charge is also levied)	=	0.1700

The WWPPT productivity appears to be attractive when compared to the cost of purchase of electricity.

Demonstrated usefulness

The European manufacturer described in the ASEAN-EC Cogen report apparently has considerable experience in delivering WWPPT and appears to have been active in ASEAN since 1975. No information is available on how many such installations are in operation throughout the world.

Application of OCCC

Based on the information available in the ASEAN-EC Cogen report, the assessment of the proposed WWPPT using the OCCC is presented.

Scale of operation

Based on the capital costs, it appears that the WWPPT under discussion is suitable for medium and large companies in the ASEAN region. It may however not be suitable for small-scale companies which, besides not being able to raise the kind of capital required, are unlikely to have scales of operation that will produce the 3,150 tons of wood waste required per month to feed the 2.5MW power plant.

Labour intensity

The labour requirements for operating WWPPT appear to be easily available in the ASEAN region. The required engineers, operators and skilled workers are likely to be obtained without difficulty. Of course specific training may be necessary to ensure a good understanding and proper usage of the technology.

Durability

The depreciation for the main equipment has been made over a period of 20 years. This length of time may be considered to reflect the durability of the equipment. Considering the nature of the equipment outlined in Table 3 it appears that maintenance will not be difficult and is well within the capabilities of the engineers and technicians in the ASEAN region.

Ease of operation

Standard operating procedures for operating the plant can be easily learnt. However, good plant management practices have to be taught during the training, not only with respect to operations but also in maintenance.

State-of-the-art

It appears that WWPPT is not currently used extensively in the ASEAN region despite the promise

From an organisational perspective the use of WWPPT is beneficial because it complements existing wood-processing technologies in the firm and substitutes for the inefficient and polluting incinerating units currently in use

it holds of significant benefits. However, there is insufficient information in the ASEAN-EC Cogen Programme report to assess how the technology offered by the European supplier rates *vis-à-vis* WWPPT supplied by Japanese, Korean, Taiwanese or Chinese manufacturers (who have also made significant progress in these technologies) in terms of both technical performance and cost.

Interaction

From an organisational perspective the use of WWPPT is beneficial because it complements existing wood-processing technologies in the firm and substitutes for the inefficient and polluting incinerating units currently in use. Its use is contingent upon the availability of wood wastes.

Application of ODCC

Using the information available in the ASEAN-EC Cogen Programme report an assessment of the proposed WWPPT using the ODCC will be carried out.

Supplier actions

The European company providing WWPPT appears to have targeted countries in the ASEAN region, especially Malaysia and Indonesia, for its sales. This is an advantage for firms in these countries that are interested in adopting the technology because they can expect a much better service from the supplier. Incidentally the supplier also seems to have had previous experience in the region having operated from Singapore until 1983.

It is interesting to note that a COGEN subsidy (15% discount on the machinery cost) is available to selected potential buyers. The supplier is also prepared to offer financial facilities (such as soft loans) that competing suppliers cannot offer. This is an advantage for the buyer. In addition, buyer credit facilities are offered by some institutions in Europe for the purchase of WWPPT from European firms.

Government actions

The ASEAN-EC Cogen Programme does not have comprehensive information on the promotional and regulatory measures currently being enforced by the ASEAN governments. However, it appears that the Ministry of Science Technology and Environment of Malaysia is in the process of enforcing prevention of pollution due to wood wastes. This may act as an incentive to timber complexes to adopt WWPPT.

Sectoral effectiveness

This technology contributes directly to the power and industrial sectors by helping to save electricity which could then be used to meet the increasing demand in industries where cogeneration possibilities do not exist, and households. In addition, in some instances, the excess power generated could be sold to the national grid thereby strengthening national power generation capacity.

Raw material requirement

The WWPPT uses only locally available raw material. However, seasonality in terms of supply could be a factor. Deterioration of the wood wastes during storage prior to use, high storage costs due to the bulky nature of wood wastes, and the costs of treatment of the wood wastes prior to use tend to increase costs of raw material storage and preparation.

Import substitution

In countries like Malaysia, Brunei and Indonesia which produce their own oil, the use of WWPPT does not reduce the importation of oil. However, it releases more oil for export. On the other hand, if this technology were used in countries such as Thailand and the Philippines, there could be savings in terms of oil imports.

Rural orientation

This criterion may not be of direct relevance to WWPPT. However, it indirectly helps rural households by not adversely affecting their livelihood as discussed below under socio-cultural stabilisation. Also, energy cogeneration and the supply of excess power to the national grid could enhance rural electrification programmes, thereby opening up more development opportunities in the rural areas.

Delocalisation

WWPPT can be easily diffused into localities where timber complexes are in operation and where the required wood wastes are available.

Income disparity reduction

It is difficult to draw a link between the use of WWPPT and income disparity reduction. However, as pointed out above under rural orientation, the supply of excess power generated by the wood processing industries, through the use of WWPPT, to the national grid could foster rural development.

Socio-cultural stabilisation

The use of WWPPT can reduce the pollution caused by dumping vast quantities of wood wastes into rivers. Its use will therefore not adversely affect the livelihoods of the rural folk who earn a living through fresh water fishing and cultivation and may actually benefit them.

Local ownership

Since WWPPT is not a highly advanced technology, the outright purchase of it will not involve foreign equity participation. However, the manufacture and supply of WWPPT, perhaps on a turnkey basis, would most probably involve the formation of a joint venture between the European supplier and an ASEAN firm. In any case there is likely to be a considerable degree of local ownership.

Appropriateness of WWPPT

On the whole it appears that, with respect to all the criteria, the proposed WWPPT offered by the European supplier is favourable. However, when several alternative suppliers are available, for instance from the USA, Japan, Korea, Taiwan or China, the same analysis has to be carried out for each technology on offer. The results may then be tabulated and the most suitable offer can be selected. Techniques such as the analytical hierarchy process (AHP) of Saaty,[67] or the profile, checklist, scoring or frontier models of Souder[68] may be used for this purpose.

One of the advantages of the proposed integrated approach is that it facilitates a more comprehensive evaluation of alternative technologies. For instance, the use of diesel generators to generate power is an option that some wood processing industries may wish to consider: they are superior to WWPPT with respect to the following criteria.

Technological complexity

Diesel generators are easy to use. When compared to WWPPT, they need less space, cost less to install and maintain, and do not require the extensive raw material storage and preparation facilities that WWPPT does.

Cost

The capital cost of a 2.5MW WWPPT (3,125,821 ECU) is significantly higher than an equivalent diesel generator, which, based on estimates from Shrestha and Bhattarai,[69,70] may cost in the range of US$1,800,000 to US$2,740,000 (1,440,000 ECU to 2,192,000 ECU), depending on the tariff structures in the country and the bargaining power of the buyer.

Demonstrated usefulness

Diesel generators have been used extensively throughout the world. Their reliability and performance have been well accepted.

Scale of operation

Diesel generators are available even for small-scale companies, unlike WWPPT which is generally viable only for medium- and large-scale companies.

Durability

Since diesel generators have been used extensively for many years, maintenance procedures have been well established.

Ease of operation

Learning to operate a diesel power plant is not difficult. In fact the standard practices with respect to plant operation and maintenance have been well established while for WWPPT they are relatively new.

Raw material requirements

There is no seasonality in terms of fuel supply. Also the complexities of storage associated with WWPPT do not apply for diesel generators.

Other criteria

In terms of quality characteristics, labour intensity, state-of-the-art, delocalisation and local ownership both WWPPT and diesel generators have similar attributes.

With respect to financial criteria such as utility-adjusted price ratios, productivity and profitability it is not possible to draw firm conclusions due to the non-availability of standard data. Market prices vary depending on a variety of factors and the complex analysis needed to make the comparison is beyond the scope of this paper. However, in general, as the price of diesel increases, WWPPT is likely to become more attractive financially.

With respect to criteria such as energy intensity, ecological stability, waste recycling, interaction, supplier actions, government actions, sectoral effectiveness, import substitution, rural orientation, income disparity reduction and socio-cultural stabilisation, WWPPT is superior to diesel generators.

Thus when WWPPT and diesel generators are evaluated for appropriateness, the choice decision would depend not only on the criteria used but also on the characteristics of the operating domain. If only technological complexity, quality characteristics, cost, demonstrated usefulness, scale of operation, labour intensity, durability, ease of operation, state-of-the-art, raw material requirements, delocalisation, and local ownership are considered, then a diesel generator would be chosen.

In a period of falling or stable oil prices, even the inclusion of criteria such as utility-adjusted price ratio, productivity, and profitability is still likely to tilt the scales in favour of diesel generators. However, if oil prices are increasing, the latter three criteria may make the choice of WWPPT more attractive.

It is important to note that, if criteria such as energy intensity, ecological stability, interaction, supplier actions, government actions, sectoral effectiveness, import substitution, rural orientation, income disparity reduction and socio-cultural stabilisation are also included, it is likely that WWPPT would be considered superior to diesel generators under both the market conditions described above.

Concluding remarks

The main aim of this paper is to deal with the difficult question of technological choice. Very often the discussions tend to become complicated, with critical issues getting buried under a mass of jargon which means different things to different people. For instance, appropriate technology is interpreted in a variety of ways by different analysts.

One of the primary objectives of this paper is to provide a simple integrated approach that could place the whole issue of technological choice in perspective. This approach stresses that firms in developing countries should choose technologies based on a balanced set of relevant criteria that would reflect the concerns of technologists, managers and government, while ensuring that the probability of success and expected returns through the adoption of the chosen technology are enhanced.

The approach has been illustrated by assessing wood waste power plant technology (WWPPT) for use in ASEAN countries and comparing it with the use of a diesel generator. It is shown that the WWPPT appears to be suitable biomass-based technology where there is a good supply of wood waste.

This analysis shows that the great advantage of the proposed integrated approach is its ability to provide a means to escape from the myopic and monocular approaches that have been used in the past to evaluate the appropriateness of a technology. The multi-faceted perceptions that are made possible by the proposed approach can facilitate the incorporation of a wide range of factors that have hitherto received scant attention.

It must, however, be pointed out that the problem of technology choice does not end with the selection of a suitable technology. An equally important issue is how to transfer this technology to the potential user and the choice of an appropriate mechanism for effecting the transfer. This aspect, though beyond the scope of this paper, should be a matter of concern to managers in developing countries who hope to acquire technologies from the industrially advanced and newly industrialising countries.

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