Feasibility of DSM-technology transfer to developing countries

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Abstract

This study sought to determine a methodology for enabling the demand-side management (DSM) technology transfer to developing countries. Readily available economic and social indicators, supported with a more detailed end-use research, were used to decide which technologies were suitable for a given developing country. Case studies were performed in N. Cyprus and Turkey to validate the theory. In N. Cyprus, DSM-technology transfer would be more successful in the residential and commercial sectors, whereas in Turkey it would be more feasible to consider DSM options in the industrial sector.

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1. Introduction

Utility demand-side management (DSM), is a way of managing the demand for power by encouraging the customers to modify their level or pattern of electricity usage. DSM was applied with some success in the developed countries and especially in the USA. At least 92 technologies were listed in the literature [1–3] that were used in the USA for providing strategic conservation, peak clipping, peak shifting, valley filling, flexible demand and strategic growth on the utility load shape. A list of these technologies can be seen in the Appendix. There have been some problems in transferring DSM to developing countries.

Painuly et al. [4] identified the barriers to the implementation of conservation programs for India on both supply-and-demand sides in six categories. These categories...
were listed as technical, institutional, financial, managerial, pricing policies and information diffusion. Cooperation among the utilities, the government, the consumers and the equipment manufacturers were seen as necessary measures to speed up the implementation of DSM programs. Reforms in electricity-pricing policies were also suggested for providing incentives for conservation. Parikh et al. [5] went a step further and conducted a DSM survey to determine the extent of awareness, perceptions of barriers and the role of policies about DSM options in the Indian industry. They showed that the major barrier to the implementation of DSM programs was the prices of the DSM technologies and the most preferred type of incentive by the industries was a one-time cash rebate. In another study, Yang [6] explained how DSM technologies were ignored in China for decades due to a centralized economy copied from the former Soviet Union. It was due to this fact that China could not produce enough peak-valley current meters with the result that the peak-valley tariff schedules could not be used.

In this study, a methodology is outlined whereby the applicability of DSM technologies to a certain developing country is examined. The study attempts to develop a methodology to answer the question: “Which DSM technologies are feasible to apply in developing countries?” Some DSM technologies may be feasible in some developing countries, while they might not be at all applicable in others. For instance, in a recent study [7], compact fluorescent lamps (CFLs) were advised as a DSM measure for Northern Cyprus, however, this program may not be suitable for other developing countries. In Turkey, low-income people living in the shanty towns at the outskirts of big cities would most probably find this program luxurious, and even if they were given a full rebate for CFLs, they might prefer selling the lamps rather than using them for themselves. On the other hand, in the villages of Bangladesh, 90% of the energy required for lighting is supplied from petroleum products and only 10% comes from electricity [8]. There, CFLs are not even worth considering as a DSM option.

As a result, it can be argued that utmost care must be exercised in proposing DSM technology transfer to the developing world. The currently available DSM technologies, developed for the industrialized western societies, are not applicable to some of the socially and economically less advanced developing-countries. Moreover, one of the major requirements in choosing the right DSM technology (option) for a country (or geographic area) is accurate information on electricity demand by different sectors and end-uses. Because these data are not readily available in many developing countries, methods need to be developed where the end-use information is obtained easily at a reasonable cost.

In this paper, a methodology is proposed where economic and social indicators together with detailed end-use information are used to determine the suitability of the DSM technologies to a developing country.

2. How economic development is measured?

The statistical information, which indicates the level of economic development, can be used in the DSM decision-making process. The economic development can
be measured through a number of social, economic and demographic indexes (indicators). The following indicators are often used to measure the economic development of a country.

a. **Per capita income**: This is a statistic that is seldom readily available and Gross National Product (GNP)\(^1\) or Gross Domestic Product (GDP)\(^2\) per capita is very often used instead. According to 1999 GNP per annum per capita, calculated using the World Bank Atlas method\(^9\), the following grouping of countries is possible: low-income, $755 or less; lower-middle-income, $756–2995; upper-middle-income, $2996–9265; and high-income, $9266 or more.

b. **Per capita purchasing power**: This is a more meaningful measure of actual income per person, since it includes not only income, but also the price of goods in a country. Table 1 shows a list of some OECD countries and their 1999 GDPs. Here the per capita GDP is expressed both by using the current exchange rates, in billion USD, and by using the current purchasing power parities (PPPs). PPPs are the number of currency units required to buy goods equivalent to what can be bought with one unit of the currency of the base country or with one unit of the common currency of a group of countries. In Table 1, PPPs are given in national currency units per US dollar.

c. **Economic structure of the labour force**: In the USA and Western Europe, fewer than 2% of the workers are engaged in agriculture, whereas in certain African nations, India, and China, more than 70% of the labourers are in this sector. More than 75% of the US labourers are engaged in wholesaling,

\[\begin{array}{|c|c|c|c|}
\hline
\text{Countries} & \text{Total GDP} & \text{Per Capita GDP} \\
\hline
& \text{Using current PPPs} & \text{Using current exchange rates (billion USD)} & \text{Using current PPPs} & \text{Using current exchange rates USD} \\
& \text{Billion USD} & \text{% of OECD total} & \text{USD} & \text{OECD = 100} \\
\hline
\text{United States} & 9190.4 & 37.1 & 9190.4 & 33 900 & 152 & 33 900 \\
\text{Turkey} & 416.5 & 1.7 & 194.5 & 6300 & 28 & 3000 \\
\text{Mexico} & 786.3 & 3.2 & 475.1 & 8100 & 36 & 4900 \\
\text{Korea} & 743.1 & 3.0 & 410.2 & 15 900 & 71 & 8800 \\
\text{Greece} & 155.7 & 0.6 & 124.7 & 14 800 & 66 & 11 800 \\
\text{Japan} & 3104.7 & 12.5 & 4380.1 & 24 300 & 110 & 34 500 \\
\text{OECD total} & 24 742.8 & 100.0 & 24849.6 & 22 300 & 100 & 22 400 \\
\hline
\end{array}\]

\[^1\] Gross National Products (GNP) is the dollar value of all goods and services produced in a nation’s economy, including goods and services produced abroad.

\[^2\] Gross Domestic Product (GDP) is a measure of the value of all goods and services produced by the economy. Unlike gross national products, GDP only includes the values of goods and services earned by a nation within its boundaries.
retailing, professional and personal services (including medical, legal and entertainment) and information processing (such as finance, insurance, real estate, and computer-related fields [11].

d. **Consumer goods purchased:** The quantity and quality of consumer goods purchased and distributed in a society are also good measures of the level of economic development in that society. Televisions, automobiles, home electronics, jewelry, watches, refrigerators and washing machines are some of the major consumer goods produced worldwide on varying scales. For instance, the ratio of persons to television sets in developing countries is 150 to 1, and population to automobiles is 400 to 1. In California, the ratio of these consumer items is almost 1 to 1 [11]. The number of consumer goods such as telephones and televisions per capita is a good indicator of a country’s level of economic development.

e. **Education and literacy of a population:** The more men and women, who have attended school, usually the higher the level of economic development in a country. The “literacy rate” of a country is the proportion of people in the society who can read and write.

f. **Health and welfare of a population:** Measures of health and welfare, in general, are much higher in developed nations than in less-developed ones. One measure of health and welfare is diet. Most people in Africa do not receive the UN daily recommended diet allowance. People in less-developed countries also have poor access to doctors, hospitals and medical specialists.

g. **Per capita energy consumption:** The energy consumption of the population is a good indicator of a country’s level of economic development.

### 3. Methodology

There may be more indicators of economic development to list, but what is sought for the purpose of this work is preferably a list of readily available indicators, for deciding on the feasibility of the DSM technology transfer. The indicators, which may be readily available, are listed in Table 2.

The indicators listed here will only give an idea about the level of the economic development of the country in question. However, more information is needed for choosing the correct DSM option. Details on the characteristics of end-uses which are seldom available in developing countries would be a very useful indicator. These data can be obtained by either monitoring, auditing or surveying. In a recent study [12], it was found that surveying is the least-time consuming, and a low-cost method to obtain such data. To generalize the method, the indicators can be grouped under two headings; macro and micro indicators (see Fig. 1).

The macro indicators are those, which will be useful in determining which of the following categories the developing country belongs to. The categories are:

a. **Advanced developing-countries:** These are the countries with middle-income which are advanced industrially.
b. Developing countries: The low-income and lower-middle-income countries that are developing.

c. Least-developed countries: The low-income countries that are either not developing or developing very slowly.

The determination of which category a country belongs to will be based on a cross check of macro and micro-level indicators. The execution of the decision-making is carried out through a consideration of the variables shown in Fig. 2. Using the end-use information, the available DSM options can be determined from the pool of DSM technologies. The applicability of the DSM technologies to the country in

<table>
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<tr>
<th>Indicators</th>
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<tbody>
<tr>
<td>Gross domestic product (GDP)</td>
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<tr>
<td>Gross national product (GNP)</td>
</tr>
<tr>
<td>Income per capita</td>
</tr>
<tr>
<td>Per capita energy consumption</td>
</tr>
<tr>
<td>Installed capacity</td>
</tr>
<tr>
<td>Capacity factor</td>
</tr>
<tr>
<td>Energy intensity</td>
</tr>
<tr>
<td>Growth rate</td>
</tr>
<tr>
<td>Income distribution</td>
</tr>
<tr>
<td>Carbon emissions</td>
</tr>
<tr>
<td>Carbon intensity</td>
</tr>
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</table>

**Fig. 1.** Macro and micro-level input variables.
question is then further examined by using information about the category of the country. The final decision is made, by checking the cost-benefit ratio of the applicable DSM program.

Finally, the implementations of the DSM programs are evaluated and if there are any doubts about their success, more surveys may be conducted in order to update the data at the micro level. The flow chart in Fig. 3 shows a simplified approach that was applied for determining the best applicable DSM technologies for Northern Cyprus and Turkey [9]. In this simple approach, the GNP per-capita income of the country in question is used to determine the income level of the country. At the same time, a decision is made about the industrial development level of the country. For this reason, the share of electricity consumption is used. This synthesis is carried out at the macro-level, leading to the setting of priorities by considering the sectors with the best applicability of DSM options. However, in order to determine the specific DSM options to apply, detailed information on the end-uses will be required. Therefore a survey is conducted for this purpose and DSM programs are proposed.

4. The cases of Northern Cyprus and Turkey

The two countries that were studied in this work are Northern Cyprus and Turkey. Northern Cyprus, being part of a small island, is not an industrially-advanced country. Sector-based electricity consumption shares are given in Table 3. The
Fig. 3. A simplified approach for DSM technology transfer to developing countries.
residential share of electricity use is the highest. A great majority of the population (68% by the 1996 figures) is employed in the services sector and hence the DSM measures are best selected from the residential and commercial technologies. Because the 1996 GNP per capita is $4222 USD, Northern Cyprus is an upper-middle-income country according to the World Bank criterion. The population is highly educated and the literacy rate is almost 100%. With these macro indicators, it was decided that the residential and commercial sectors would have the best potential for load reduction and the DSM technology-transfer should be considered for these sectors. Surveys were conducted in both sectors to determine the micro indicators leading to the selection of the DSM options to apply.

In the residential sector, statistical information was obtained on the number of electrical appliances and their time of use and end-use load curves were obtained. It was discovered that electrical water-heaters demanded 50 MW at the winter peak-hour (19:00), which constituted 45% of the 110 MW peak. The shares of end-use demands of the winter peak can be seen in Fig. 4. DSM programs concerning water heating, space heating and lighting activities were proposed. It was estimated that DSM technology transfer in these end-uses was highly cost-effective. They would defer the need for a $100 million US dollars worth, 60 MW new power unit for at least 19 years at the expense of $12 million US dollars [7].

The diversity of the commercial buildings and their end-uses precludes the adoption of the approach used in the residential sector. Not only the system sizes for end-uses vary greatly, but also their time of use may also vary for different building types. The problem can be simplified by selecting a segment of the commercial sector. In Northern Cyprus, tourism was selected, being the most electricity-consuming segment in the commercial sector. According to the surveys conducted, the power demand of this sector is more during the summer season with the heavy use of air-conditioners. Air-conditioner use in the hotels constituted 27% of the utility load in summer [12]. The proposed DSM technology transfer to this sector could reduce the summer peak by 14% with a total cost of $560,000 US dollars.

Turkey, on the other hand, is an advanced developing country, due to its last two decades of industrial development. The primary energy-consumption share of the

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>35.04</td>
</tr>
<tr>
<td>Commercial</td>
<td>18.74</td>
</tr>
<tr>
<td>Industrial</td>
<td>9.39</td>
</tr>
<tr>
<td>Agricultural</td>
<td>7.28</td>
</tr>
<tr>
<td>Defense</td>
<td>10.24</td>
</tr>
<tr>
<td>Street lighting</td>
<td>1.90</td>
</tr>
<tr>
<td>Utility use</td>
<td>5.82</td>
</tr>
<tr>
<td>Grid losses</td>
<td>11.59</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>
industrial sector is currently 29% and is expected to reach 40% in 2020. However, due to its non-uniform income distribution, the 1999 GDP per capita is $2807 USD [10], which makes Turkey a lower-middle-income country. The level of education is low, and a rebate program on changing the incandescent lamps with CFLs in the residential sector, is not expected to be as successful as in Northern Cyprus, especially with the low-income homes. The macro-indicators of Turkey imply that the transfer of DSM technology would be best selected from the industrial options. Micro indicators such as end-use fuel types and the magnitudes of power and rate of heat demands of the factories, pointed to sizable energy-gains from a cogeneration program. A more detailed study [12], showed that the country’s primary-energy saving potential, of utilizing a cogeneration system in the manufacturing industry, would be between 30 and 45%. This was another micro-indicator influencing the final decision-making.

5. Conclusions

In this study, methodologies were developed to enable DSM technology to be transferred to residential, commercial and industrial sectors of the developing countries. Although these methods were developed and tested in Northern Cyprus and Turkey, the material presented provides a foundation for success in future DSM planning and implementation in other developing countries. It is possible to analyze the feasibility of a DSM technology-transfer to any specific developing country by adopting a similar approach to what is presented in this paper. The synthesis of the macro and micro indicators, however, may slightly differ for each country.
## Appendix. Demand-side management technologies [1–3]*

<table>
<thead>
<tr>
<th>Residential measures</th>
<th>PC VF LS SC SG FL</th>
</tr>
</thead>
</table>

### Building structure

1. Insulation
   - a. Walls
   - b. Ceiling
2. Radiant barriers
3. Foundation insulation
   - a. Basement exterior
   - b. Crawl space interior
   - c. Slab-on-grade exterior
4. Windows
   - a. Triple pane
   - b. Low E-glazing
   - c. Gas filled
5. Storm Windows
6. Window treatments
   - a. Movable insulation
   - b. Solar control
7. Weather stripping
8. Passive solar design

### Heating, ventilating and air conditioning

9. Heat pumps
10. Whole-house and ceiling fans
11. Heat storage
12. Zoned heating
13. Energy-efficient air-conditioning
14. AC cyclic control
15. Duct thermal losses
   - a. Duct leaks
   - b. Duct insulation
16. Distributed photovoltaic-systems

### Water heating

17. Domestic water-heating
   - a. Water-heater blanket
   - b. Thermal traps
   - c. Pipe wrap
   - d. Low-flow shower head

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18. Heat pump
   a. Water heaters
   b. Heat-recovery water heaters
19. Solar water heaters
   a. Drainback system
   b. ICS
   c. Thermosyphon glycol loop
20. DHW cycling control

**Lighting**
21. Incandescent alternatives
   a. Efficient incandescent
   b. Compact fluorescent
   c. Efficient interior
   d. Incandescent floodlights
   e. Efficient exterior-floodlights
   f. Tungsten/halogen lamps

**Appliances**
22. Energy-efficient refrigerators and freezers
23. Low-water clothes/dishwashers
24. Moisture sensor clothes-dryers
25. Cooking equipment
   a. Improved cooktops
   b. Induction cooktops
   c. Improved oven

**Swimming pools/spas**
26. Pool/spa pump control
27. Solar pool heaters/covers

**Commercial measures**

<table>
<thead>
<tr>
<th>PC</th>
<th>VF</th>
<th>LS</th>
<th>SC</th>
<th>SG</th>
<th>FL</th>
</tr>
</thead>
</table>

**Building structure**
28. Fenestration
29. Passive solar design

**Heating ventilating and air conditioning**
30. Heat-recovery from exhaust air
31. Outside-air economizers
32. Evaporative cooling
33. Cool storage
34. Heat recovery from chillers
35. High-efficiency air conditioning
36. Heat pumps
37. Energy-management systems
Lighting
38. Fluorescent Lamps
   a. High-efficiency lamps
   b. Electronic ballasts
   c. Reflectors
   d. Combination
39. Exit light conversion
40. High-intensity-discharge lamps
   a. High-pressure sodium
   b. Low-pressure sodium
41. Light sensors/controllers
   a. Ultrasonic occupancy sensors
   b. Photocell
42. Day-lighting controllers

Hot water
43. Water heater retrofits
   a. Booster heater
   b. Reduce hot-water circulation

Refrigeration
44. Refrigeration systems
   a. Multiplex compressors
   b. Floating-head pressure control
   c. Ambient subcooling
   d. Mechanical subcooling
   e. Hot-gas defrost
   f. Evaporative condenser
   g. Display-case glass doors

Cooking
45. Cooking equipment
   a. Energy-efficient fryer
   b. Combination steamer/oven

Motors
46. Energy-efficient motors
47. Adjustable-speed drives
48. Polyphase motors
49. Motor oversizing
50. Motor rewinding
51. Wire sizing
52. Power-supply tune-up
53. Maintenance
54. Transmission efficiency
Industrial measures

**Cooling systems**
- 55. Condenser-water temperature reset
- 56. Chilled-water supply temperature reset
- 57. Hot-gas defrost
- 58. Two-speed motors on cooling-tower fan

**Heating systems**
- 59. Destratification fans
- 60. Comfort radiant-heating systems
- 61. Process radiant-heating systems
- 62. Quartz radiant-heating systems

**Boilers**
- 63. Combustion air-blowers variable-frequency drives
- 64. Air/fuel ratio reset
- 65. Turbolators
- 66. High-pressure condensate return systems
- 67. Steam-trap repair
- 68. Steam leak repair

**Air compressors**
- 69. Outside-air usage
- 70. Leakage reduction
- 71. Cooling-water heat recovery
- 72. Waste-heat recovery
- 73. Pressure reduction
- 74. Screw compressor controls
- 75. Compressor replacement
- 76. Low-pressure blowers

**Insulation**
- 77. Steam lines and hot-water pipes
- 78. Chilled-water pipes
- 79. Hot tanks
- 80. Cold tanks
- 81. Injection mold barrels
- 82. Dock doors

**Industrial process heat recovery**
- 83. Industrial process heat-exchangers
- 84. Waste-heat recovery boilers
- 85. Cogeneration
- 86. Industrial process heat-pump
Solar energy
87. Solar industrial process heating
88. Once-through solar heated ventilation and process air
89. Solar photovoltaic water-detoxification

Electric-use shifting and controls
90. Demand controls
91. Interruptible and curtailable service
92. Power factor

a PC = peak clipping; VF = valley filling; LS = load shifting; SC = strategic conservation; SG = strategic growth; FL = flexible load-shape.

References