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EVALUATING LOAD MANAGEMENT POTENTIAL

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Demand-side management (DSM), particularly the load management, provides electric power utilities a flexible way of meeting the peak load in a production schedule and a demand-side resource of dispatchable capacity. At that DSM is an environmentally friendly technology enabling to save fossil fuels and reduce pollutant emissions. So DSM programs can be viewed as the least-cost energy resource when both environmental costs and welfare needs are considered. Therefore electric utilities as well as governments have increasing interest in DSM to promote energy efficiency, and achieve cost-effectiveness for both utilities and consumers, mainly by deferring the need to build new power plants. With this interest, there is an increasing need for evaluation of DSM potential in initial stages of elaborating corresponding programs. This paper presents the main results of a study for evaluation of load management potential and its techno-economic viability conducted by the Department of Electrical Power Engineering of Tallinn University of Technology. The applied methodology can be used as the basic framework for quick preliminary evaluation of the load management potential and its main economical characteristics.

Introduction

The electric utility industry is undergoing big changes in Estonia. These changes affect utility motivations and perspectives, and further, the changes may also influence the role played by other parties, such as governments and energy suppliers. One of the least-cost resources to cope with new challenges that has been implemented in many countries worldwide over the past several decades but has remained aside the attention of Estonian energy planners is utility-sponsored demand-side management (DSM).

To start to overcome this shortcoming, an evaluation of load management potential and its techno-economic viability compared to other peak covering possibilities was conducted by the Department of Electrical Power Engineering of Tallinn University of Technology on the request of the

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Estonian Ministry of Economic Affairs and Communication. This paper presents the main results of the study.

Due to limited time resource given by the sponsor and lack of sufficient statistics, the study presented in this paper should be treated as a preliminary one with the aim of producing more detailed DSM studies, including evaluation of customer acceptance, and plans for implementation in future in the framework of Integrated Resource Planning to create long-term energy efficiency improvements.

Demand-side management consists of the activities and policies of electricity supplier or other party (such as the Government, authorities, etc., apart from the electricity consumer) that are designed to encourage consumers to modify their level and pattern of electricity usage. Principally DSM programs include next main categories [1]:

Load Management programs which are aimed at changing load curves of customers, particularly at reducing consumption during periods of peak demand. Direct load control is a reliable means to provide a demand-side resource of dispatchable capacity as well. In general, load management has a small effect on total energy consumption.

Energy Efficiency programs are aimed at reducing the energy consumed by end-use devices and systems. These programs reduce overall electricity consumption over many hours during the year, although the greatest impacts of the programs often coincide with periods of peak usage.

Load Building programs are aimed at increasing the use of existing electric equipment or the addition of electric equipment such as infrared drying, cooking, heat pumps, etc. Load Building includes programs that promote the substitution of electricity for other forms of energy. Load Building promotes load growth.

Other DSM programs refer to such ones as market transformation, promotion of offering consumers other types of energy instead of electricity, promotion of self-generation of electricity for the consumers' own use, use of energy storage, etc.

The study in question is focused on the evaluation of load management potential. The main strategies of load curve modifying enabling to defer capacity addition, minimize average losses and increase utilization are peak clipping, valley filling and load shifting, which are normally used in conjunction. Load management may be segmented into three approaches: direct load control, interruptible load control and indirect load control [1, 2].

Direct Load Control is achieved through direct disconnection and reconnection of appliances by the electric utility, or modifying the operation of individual end-use devices or equipment. Direct Load Control usually involves residential consumers who allow the utility to interrupt the service to certain appliances (water heaters, electric space heating devices, air conditioners, refrigerators, etc.) periodically during the hours of peak load.

Interruptible Load accounts for the consumer load that, in accordance with contractual arrangements, can be interrupted either by direct control of the electric utility system operator or by action of the consumer, at the direct request of the system operator, usually as a strategy to reduce peak load but in emergency situations as well. Interruptible loads were not comprised by the present study.

Indirect Load Control is achieved mainly *via* a time-differentiated electric rate structure to encourage the desired time shift of electricity consumption from on-peak to off-peak or high-cost to low-cost periods. Information and training of customers, advertising campaigns, etc., are other possible ways of indirect load control.

The main benefits of load management are:

- for electricity producers – possibilities to choose the most effective ways to cover growing demand for electricity services and to defer investments for expanding generating capacities, to decrease the need of peak load sets and reserve power, to improve utilization of existing capacities and reducing marginal costs of generating;
- for transmission and distribution enterprises – possibilities to defer investments for expanding transmission and distribution capabilities and reducing network losses;
- for manufacturers of electric appliances and technologies – increase in both the market share of energy-efficient appliances and technologies and promotion of their development;
- for end-users – cheaper electricity bills and production costs, and thus increase in their competitiveness;
- for the entire society – increase in energy efficiency and competitiveness of the domestic goods, saving domestic energy resources and reducing needs for imported energy resources, decrease in the damage to atmosphere and ecosystem caused by electricity production.

It should be especially underlined that there is a considerable need for maneuvering capacities in Estonian power system to cover rapid load changes. In particular it is relevant to integrate wind power installations into the system, which are quickly developing in Estonia. In this context the load management would give in disposal of the system operator a valuable additional dispatchable capacity.

The DSM programs and integrated resource planning as a demand-oriented concept were popularized extensively in the United States since the ‘70s. Soon they were implemented in the practice of European electric utilities, particularly in EU countries, and have become increasingly useful over the last decades [3]. Today the DSM programs are used in many countries worldwide. In many countries various regulations are established to accelerate implementation of DSM programs [1]. Different levels of evaluating DSM options and groups of DSM are analyzed in [2, 4, 5].

Evaluating of the Direct Load Control Potential

The potential of peak load reducing depends on providing the customers with appliances suitable for direct load control, on the character of their consumption and on the acceptance of customers to participate in load management programs, and, on the other hand, on the character of the system load curve, particularly on the load factor of daily load curves and peak durations. In the case of high load factor the peak reducing potential is small, and – *vice versa* – in the case of low load factor the potential may be reasonable [6]. In general, on the ground of experience, the peak reduction potential is considered to be highest if the duration of daily load peaks is less than three hours [7].

Peak load reductions by direct load control (measured in megawatts (MW)) are categorized as potential or actual [1]. Potential peak load reduction is the amount of load available for curtailment through direct load control. Actual peak load reduction is the amount of reduction that is achieved from direct load control programs that are put into force at the same time as peak load. As the direct load control is not in actual use in Estonia nowadays, the actual peak load reduction by direct load control is practically zero in Estonia, and only potential peak load reductions can be considered.

Potential Accrued from Providing Customers with Electric Appliances

Direct load control is used primarily to manage residential consumption and, to a limited extent, in business and public sectors. In Estonian conditions it is reasonable to consider residential customers as well, who are the main causers of the evening load peak. For the direct load control are suitable electric appliances, which, disconnected by the power system operator, will not cause considerable inconvenience for customers, in the first order appliances related to heat generation and such having a certain energy storage ability. The most common appliances comprised by the direct load control are air conditioners, heat pumps, electric water heaters and heating devices.

At that the duration of switching-off must be sufficiently short – 0.25–4 hours and take place after sufficiently long intervals to ensure recovery of the necessary thermal balance. Cooling and refrigeration devices are comprised with the direct load control relatively rarely because of relatively small capacity of the residential units on the one hand, and psychological reluctance of customers related to possible spoil of foods on the other hand.

As the consequence of Estonian climate conditions, potential of air conditioners is inconsiderable. All the more their contribution is highest in summer time, when the total loads as well as daily load peak are considerably lower. Provision with heat pumps is very low nowadays in Estonia. Due to high prices and a number of technical problems it can be assumed that the provision growth in the near future will not be considerable. All the more their comprising with direct load control programs is limited by the aspects related to main space heating (see below). So, the potential of the control of heat pumps can be considered practically to be zero. So, in Estonian conditions it is of main interest to use direct control of electric water heaters and electric heating devices.

Direct control of electric water heaters lies in turning them off for the control period (2–4 hours) and on when the control period is over. Considering the volume of boilers 80–150 liters and a relatively large thermal capacity of water, water temperature will not drop remarkably during the control period. Especially suitable for direct control are modern electric water heaters with two heater coils, the top coil that heats the top 20% of the water to permit a quick recovery of a small volume of water, and the lower element that heats the remainder of the tank.

Only one coil can be operating at a time. Turning a water heater from the controlled "off" condition to the "on" condition results in the operation at full capacity. This can lead to an abrupt secondary peak being created. By proper coordination, however, this may be mitigated. Direct control of electric water heaters leads to some energy savings (up to 10%) owing to energy pay-back following the control period that is in general slightly less than 100%. The interval between two control periods should be not less than the pay-back period, i.e. at least 2–4 hours.

Electric heating devices can be categorized to primary space heating, supplementary space heating and floor heating devices. Comprising primary electric space heating devices with direct load control is not expedient. Most of them have storage elements and consume, in general, electricity in the periods of night tariff in effect. Devices without storage are usually programmed in a way that during the periods of day tariff in effect their temperature set value is 5 degrees lower than during nighttime. If the system operator turns the heating device off for several hours from the moment when it was switched on for the last time by the local control program, there will be a danger of excessive indoor temperature drop.

Direct control of electric heating devices is similar to the direct control of electric water heaters: they are turned off for 2–4 hours of the control period. Due to thermal inertia indoor temperatures will not drop typically more than 2-3 ºC. Interval between two control periods should be at least 2–4 hours. Direct control of electric space and floor heaters leads to some energy savings as well.

Proceeding from the average unit capacity of the above-mentioned appliances and saturation of households with the appliances, the total capacities of them were evaluated. The sum of total capacities of different appliances can be considered the theoretical potential of the direct load management. To evaluate the actual or real total potential of direct load control, the following aspects should be considered:

- Including all appliances to the load management system is not technically feasible. Multiplying the theoretical potential by the technical feasibility factor k_{tech} gives the technical potential of direct load management.
- Comprising a part of households to the load management system may be economically not rational despite its technical feasibility. Multiplying the

technical potential by the economical feasibility factor k_{ec} gives the cost-effective potential of direct load management.

- In general, most of appliances in question have local automatic control systems. So, it may happen that in the beginning of the control period, i. e. in the moment of turning off by the system operator a part of appliances is already switched off by local control systems. So, the cost-effective potential should be multiplied by the coincidence factor k_{co}. The result will be the feasible techno-economical potential.
- The customer acceptance in participation of central load control programs has to be taken into account as well. The customer acceptance depends to a large extent on the explanation work carried out by electric utilities or corresponding authorities and on incentives proposed to customers. Multiplying the feasible techno-economical potential by the acceptance k_{acc} gives the total real potential of direct load management. This potential can be considered a resource of dispatchable capacity in hand of the system operator due to direct load control.

Thus, the real potential of direct load management can be expressed as:

$$\textit{Total real potential} = \textit{Theoretical potential} \times k_{tvech} \times k_{ec} \times k_{co} \times k_{acc}$$

However, if the main aim of the direct load control is reducing the load curve peak, the potential will be considerably lower because in full employment of the real potential secondary peaks will occur due to capacity pay-back following the control period. To mitigate these secondary peaks and maximally smooth the daily load curves the appliances involved in direct load control should be grouped and controlled in a proper way. So, the peak reduction potential by the direct load control will be:

$$\textit{Peak reduction potential} = \textit{Real potential} \times k_{sp}$$

where k_{sp} is the secondary peak factor, whose value depends to a large extent on configuration of daily load curves.

The analysis of present and forecasted daily load curves shows that in the Estonian case k_{sp} is nearly 0.5.

Estimated values of the above-mentioned influencing factors and the results of evaluation of direct load management potential for different years are summarized in Table 1.

In the future, when a sufficient direct load control experience will be obtained and when proper control systems will exist, an additional direct control resource may be proved through direct control of refrigerators and freezers. Considering the relatively short permitted turning-off duration (not over an hour) of refrigerators and freezers, their rotating control has to be implemented, dividing them into a number of groups. Due to a comparatively small capacity of refrigerators and freezers, a noticeable effect can be reached if a large number of them is subjected to the direct control. At that their control at customers, who have already involved in the direct load control system, will not cause substantial technical problems and additional costs.

Table 1. **Evaluation of the Direct Load Management Potential**

Appliances comprised in direct load control	Average unit capacity, kW/influencing factor	Total capacity, MW, in the year		
		2003	2017	2030
Electric water heaters	1.2	103	130	156
Electric radiators	1.5	36	51	65
Electric heating floors	0.6	120	140	180
Theoretical potential		259	321	401
Technical potential	$k_{tecn} = 0.9$	233	289	361
Cost-effective potential	$k_{ec} = 0.9$	210	260	325
Feasible techno-economical potential	$k_{co} = 0.5$	105	130	162
Total real potential	$k_{acc} = 0.7$	**73**	**91**	**114**
Peak reduction potential	$k_{sp} = 0.5$	**35**	**45**	**57**

Potential Accrued from the System Load Curves

To evaluate the direct load control potential proceeding from the system load curves, the present and prospective daily load curves of the Estonian power system were analyzed. It appears that the daily load curves are characterized by a very high load factor, in the range of 0.84–0.9, and that they have, in general, two peaks – morning and afternoon ones. The extents of the maximum, minimum and average morning and afternoon load peaks, their durations and hours in workdays and holidays were established for winter, spring-autumn and summer load periods. The average energy consumptions, maximum, minimum and average values of load, load factors and uniformity factors in workdays and holidays for the three load periods were determined as well. The results of the analysis are summarized in Table 2. The duration of the morning as well as the afternoon load peak is 3–4 hours. Time of load peaks shifts somewhat seasonally. In general, the afternoon load peak is higher than the morning one. At that, the afternoon peaks during the holidays are, in general, higher than these on workdays, but morning peaks, vice versa, are higher on workdays. The extent of afternoon load peaks is relatively high on some holidays of the summer period.

As one can see from Table 2, the potential accrued from the present-day system load curves is maximally 99 MW. Principally this is the dispatchable direct load control capacity needed for full clipping of daily load peaks. However, in evaluating this needed capacity it is more reasonable to proceed from the average extents of daily peaks, which is about 40–50 MW (see Table 2). This capacity can be considered the peak reduction potential by the direct load control accrued from the present-day system load curves. Table 3 presents the estimates of these potential for the future for the 3.75 and 2% load growth scenarios.

Table 2. **Results of the Analysis of Daily Load Curves for the Year 2003**

Parameter	Winter		Spring–autumn		Summer	
	Workday	Holiday	Workday	Holiday	Workday	Holiday
Average daily consumption, MWh	24,354	22,433	17,685	15,594	13,671	13,925
Average daily mean load, MW	1,015	935	737	650	570	580
Average daily load maximum, MW	1,171	1,078	868	739	685	696
Average daily load minimum, MW	800	806	551	525	399	412
Average daily load factor	0.87	0.87	0.85	0.88	0.83	0.83
Average daily load curve uniformity factor	0.68	0.75	0.63	0.71	0.58	0.59
Average afternoon load peak, MW	44.8	57.8	32	45	15	15
Average morning load peak, MW	28	11	33	14	13	10
Maximum afternoon load peak, MW	89	85	73	99	25	77
Minimum afternoon load peak, MW	18	20	0	0	0	0
Maximum morning load peak, MW	86	47	112	32	25	24
Minimum morning load peak, MW	0	0	3	0	0	0
Hours of afternoon peak	18–22	18–23	19–23	19–23	14–18	22–24
Hours of morning peak	9–14	9–14	10–13	10–13	10–13	10–13

Table 3. **The Forecast of Average Extents of Daily Load Peaks for the Years 2005–2030, MW**

Load growth rate, % per year	Year				
	2002	2005	2010	2015	2030
3.75	45	50	60	73	126
2.0	45	48	53	58	78

As it becomes evident, the total real controllable capacity of electric appliances suitable for direct control will exceed the needed extent of direct load control in case of 2.0% load growth, and is nearly of the same order as in the case of 3.75% load growth scenario. By the other hand, the peak reduction potential (see Table 1) will be less than the extent needed for the full clipping of daily peaks, particularly in the case of 3.75% load growth. However, taking into account the additional possible resource of the control of refrigerators and freezers as well as the opportunity of direct load management in commercial and public sector, it can be assumed that clipping of the daily load peaks will be possible to the full extent in the case of effective implementation of the direct load control.

Evaluation of the Indirect Load Control Potential

The potential of indirect load management is the total load capacity by which it is possible to reduce the daily load peaks by means of indirect load control. Indirect load management is related to activities of a number of parties – electric utilities, customers, governmental and local authorities, manufacturers and suppliers of devices and fuels. The result of the control will depend to a very large extent on the reaction of customers that is hardly predictable. Thus, the evaluation of the potential of indirect load management with at least a little accuracy requires extensive tariffs and price elasticity analyses, extensive and long-time customer surveys and sufficient experience. Thus, the estimates here are based on expert awards and approximate assessment based on the experience of other countries. The main measures of indirect load control are energy saving and electricity tariff structure, particularly peak tariffs.

The difference between conventional energy conservation measures and load control measures is rather hazy. The main difference is that the primary aim of the energy savings in the case of load management is curtailment of load peaks and the customers' participation in load management programs promoted by various incentives to compensate possible inconveniences and changes of lifestyle and work rhythm. As incentive rebates, returning money, financial support, rewards, additional services, etc., calculated on the basis of avoided costs of utilities, are used [8]. In addition to direct incentives, typical commercial/industrial customers prefer such characteristics for DSM projects as quick paybacks (under 2-3 years), visible energy savings, equivalent or improved comfort and tenant and/or employee satisfaction, equivalent or improved aesthetics, quick turnaround time for project completion, longer lifetime and less maintenance of equipment, etc. [8].

A rough estimate of the electric energy saving potential is within the range of 10–30% of the present total consumption [9]. The study [10] resulted with the value of 30%. Taking into account the assessments of other countries and low energy effectiveness of electricity use in Estonia, the last estimate can be considered quite realistic. On the basis of UK experience, the potential of energy savings via the indirect load control can be assumed to be equal to about one third of the total saving potential, or approximately 10% of the total consumption.

The most effective measure of direct load management is the structure of electricity tariffs. To ensure the maximum social effectiveness of electricity use, the customers should be informed of utilities costs, depending on seasons, daytime and weather, through the electricity tariffs. Many power systems apply daytime and seasonal tariffs. From the point of view of social benefits peak load tariffs are particularly useful. Very effective is the real-time pricing when customers continuously receive price information and can monitor their consumption continuously as well. Recent advancements in communication and information technology perform implementation of real-time pricing systems in residential sector as technically and economically feasible. Real-time pricing is especially suitable for peak reducing in industrial sector.

Tentative assessments of the number and capacity of main electricity appliances running simultaneously in Estonian households are given in Table 4. Uniform distribution of possible running times over 20 hours and in the case of TV sets over 10 hours per day is assumed. Refrigerators and freezers are not included in the table because they switch off and on automatically. Electric lighting, whose main resource is related to energy saving, and electric heating devices, whose potential was taken into account in the framework of direct load control, are not considered as well. The capacities presented in the table can be considered the theoretical resource of load shifting. Thus, the theoretical potential of the indirect load control could be approximately 146 MW. However, in estimating the real potential capacity, TV sets should be counted off, because their service time depends primarily on TV programs and spectator interests.

The fact that customers using night tariff have already shifted most of their appropriate consumption to evening and night hours should be taken into account. On the other hand, a part of customers will not change their lifestyle and shift consumption in any case. Taking into account these aspects, the total potential of indirect control by electricity tariffs can be assumed tentatively 50 MW.

Table 4. **Tentative Assessments of Number and Capacity of Appliances Running Simultaneously in Service (Residential Sector)**

Appliance	Saturation, %	Total number	Average capacity, kW	Average duration of daily service time, h	Number of units running simultaneously	Capacity of units running simultaneously, MW
Washing machine	72	410,400	2.0	0.5	10,260	20.5
Dish-washing machine	1	5,700	2.0	1.0	285	0.6
Electric stove	50	285,000	2.5	1.5	21,375	53.4
Microwave heater	15	85,500	1.3	0.5	2,138	2.8
Electric kettle	50	285,000	2.0	0.3	4,275	8.6
Vacuum cleaner	85	484,500	1.0	0.3	7,268	7.3
Television set	92	524,400	0.2	5.0	262,200	52.4
Video recorder	31	176,700	0.03	1.0	8,835	0.3
					Total	145.8

Implementation of load management programs may influence customers' lifestyle and convenience (some drop of indoor and hot water temperature, shifting domestic doings into more inconvenient hours, some disturbance of production processes, etc. So, for the success of load management programs effective acceptance of customers is very important. Customers must clearly understand the aims of the programs and the arising personal and social benefits. Participation of customers is often hampered by shortage of knowledge and lack of information on energy-efficient devices and technologies and their implementation possibilities in a particular company.

Thus, for successful development of DSM programs information of customers on entity, benefits and implementation opportunities of demand-side management is urgently needed. Any kind of educational and training programs, workshops, information centers, fairs, exhibitions, etc. play important role in this area. Energy audits in companies are relevant to examine the energy situation and to find out definite opportunities to implement energy saving and load management measures. To accelerate penetration and to increase the market share of new energy effective devices and technologies, the appropriate advertising campaigns and training sessions should be conducted.

Evaluation of Economical Figures of the Load Management

Direct Load Control usually takes place by the electric utility-side signals (through radio, telecommunication, or high-frequency channels), which in turn switch off electric appliances for some hours and then on again. Electric water heaters and floor heaters can be controlled all-year-round; control of electric radiators can be considered in winter period and partially in spring-autumn period.

To simplify the assessment of economical figures, it was assumed that at an average customer a hypothetical electric appliance with peak demand of 2 kW is controlled. Load demand of the appliance changes within the range of 0.2–1.1 per unit. The load demand of the hypothetical appliance (kW/appliance) in workdays and holidays for different load periods without and with load control was modeled. With the direct control assumed to be comprised 50,000 residential customers. Daily load curves for workdays and holidays of three load periods corresponding to the real average daily load curves were designed for the analysis. On the basis of the hypothetical appliance load model the changes of demand (in MW) and consumption (in MWh) owing to load control were determined. The total annual consumption of customers comprised with load control decreased by 11,035 MWh, or in average 221 kWh per customer.

The analysis indicated that load control enabled to reduce initial load peaks by 40–50 MW but caused considerable secondary load peaks shifted from the former peaks due to “pay-back” accompanied with turning on of the appliances. The secondary peaks are most remarkable in the winter period. Thus, to get a flexible control, the appliances should be segmented into 5–10 groups, which permits to turn off and on appliances with the capacity of 10–20 MW. At that it is expedient to join various appliances of a customer to different groups. This is more convenient for customers and raises their acceptance to participate in direct load control programs.

The main **Economic Benefits** of the direct load control are the production cost savings and power system generation capacity savings. The marginal cost to cover load peaks with gas turbines was assumed 600 EEK/MWh, investment cost for installation new gas turbines were taken 10,000 EEK/kW.

Direct load control costs are revenue lost due to energy savings, investment cost for establishing the control system, control equipment operation and maintenance cost, customer incentive payments and administration costs. The average residential daytime electric rate is assumed to be 1,050 EEK/MWh, the cost of control equipment performed by means of mobile phone communication was assumed to be 4000 EEK per customer or 1,600–2,000 EEK/kW. The primary cause of control equipment operation and maintenance cost is the repair of residential receivers. A failure rate of 5% and a levelzed installed repair cost of 500 EEK/failure were assumed. The direct load control has an impact on customer lifestyle and comfort.

The customer is willing to accept this with an annual participation payment. The incentive payment of 200 EEK/year is assumed here. Administrative costs include the costs for creation of load management structures and primarily for customers' surveys and for achieving the customers' acceptance. The administrative cost of 30 EEK per an inquired customer and the number of inquired customers of 200,000 are assumed. The economic benefits and costs of direct load control at these assumptions are summarized in Table 5. Distribution of direct load control costs is illustrated in the Figure.

Table 5. **Economic Benefits and Costs of Direct Load Control**

Benefits/costs	Capitalized benefit/cost, EEK	Specific capitalized benefit/cost, EEK/kW
Benefits		
Production cost savings	31,669,565	1,056
Generation capacity savings	300,000,000	10,000
Total	331,669,565	11,056
Costs		
Revenue lost	50,377,174	
Investment cost	200,000,000	2,015
Control equipment operation and maintenance cost	5,434,783	8,000
Customer incentive payments	43,478,261	217
Administration cost	6,000,000	1,739
Total	305,290,217	10,176
Total benefits-costs	26,379,348	879

Effectiveness of the direct load control is very sensitive to the extent of real peak reduction. The latter is diminished significantly by the secondary peak due to power pay-back. So the real reduction about 30 MW instead of expected 40–50 MW was achieved. Segmenting the appliances into groups and turning them off and on rotary for shorter control periods can reduce the effect of the pay-back.

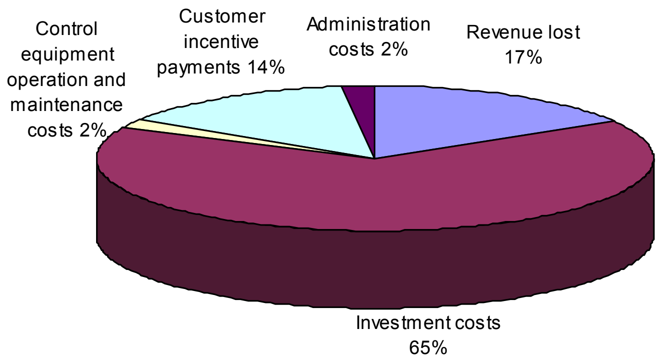

Figure 1. Distribution of direct load control costs

Indirect load control focuses on providing customers with price signals as incentives to change their electricity use patterns. Implementation of direct load control requires a well-designed rate tariff structure as well as customer metering capable of measuring the tariff billing components. For large commercial and industrial customers, the cost of metering is a small contribution to the overall cost of electricity. For residential and small commercial customers, the cost of a new sophisticated meter can be a significant cost consideration when evaluating the net benefits of indirect load control.

The main philosophy of direct load control is that the rate should be structured so that the annual customer bill is the same as the existing tariff if the customer does not alter the usage profiles. The economics of indirect load control is very project-specific, depending on tariff rates and their implementation hours, category of customers, etc.

In the current study effectiveness of establishing peak load rates for residential customers was evaluated. The consumption indices for an average residential customer were taken as follows: annual consumption during peak load hours is 700 kWh/year; consumption during off-peak hours is 1,400 kWh/year, consumption in night hours 1,100 kWh/year. So, the total annual consumption is 3,200 kWh/year. Peak-load price elasticity was assumed to be −0.30; off-peak price elasticity was taken −0.10. A new peak-load tariff applied all-the-year-round six hours per day in assumption that the customers' expenditures for electricity remain the same if they do not alter the usage profile. Marginal costs of electricity supply were assumed to be 3.00 EEK/kWh in peak-load hours, 0.66 EEK/kWh in daytime off-peak hours and 0.54 EEK/kWh at night. The failure rate of the time-of-day meters was estimated at 0.5% per year, and the repair cost was taken 200 EEK per meter. The energy consumption and savings per customer are presented in Table 6.

Table 6. **Energy Consumption and Savings**

Rate period	Existing tariff			Proposed tariff			Savings		
	Rate, EEK/kWh	Consumption, kWh	Revenue EEK/year	Rate, EEK/kWh	Consumption, kWh	Revenue EEK/year	Energy, kWh	Utility cost EEK/kWh	Utility cost savings EEK/year
Peak rate period	1.30	700	910	2.30	590	1,357	110	3.00	330.4
Off-peak rate period	1.30	1,400	1,820	0.96	1,444	1,382	–44	0.66	–28.7
Night rate period	0.75	1,100	825	0.55	1,135	624	–35	0.54	–18.7
Total		3,200	3,555		3,168	3,362	32		282.9

The overall electric utility economic benefits per customer are evaluated as (in capitalizing the levelled annual fixed-charge rate was assumed to be 23%):

	Annual benefit/cost, EEK/year/customer	Capitalized cost EEK/customer
Production cost savings	282.9	1,230.1
Revenue lost	–192.6	–837.2
Operation and maintenance cost of meters	–10.0	–43.5
Total	80.4	349.4

Accordingly, if the time-of-day meter can be purchased and installed for less than 350 EEK, the residential peak-period pricing program is economical and worth to be implemented. Obviously this is not realistic at present conditions in Estonia. It should be noticed that the peak-period pricing program is very sensitive to the relationship of marginal costs in peak-load and off-peak hours.

Conclusions

The study proved the existence of significant load management potential from the aspect of controllable appliances (first of all electric water heaters, electric radiators) as well as from the aspect of their total capacity. In the residential sector the latter is estimated to be about 70 MW at present, 90 MW in the year 2017 and 115 MW by the year 2030. At that the average extent of daily peak loads in Estonian power system in absence of load control is about 45 MW at present, reaching 60–75 MW in 2017 and 80–125 MW in 2030.

Despite that power pay-back decrease the real direct load control potential, it will be enough to clip the daily load peaks nearly to the full extent, if there a sufficient number of customers (80,000–100,000) is comprised by the direct control.

In the future, when sufficient experience has been attained and in case proper control systems are available, the control of refrigerators and freezers can be considered an additional resource. Including them into the existing control systems will not cause a significant extra cost. Considerable additional resource is the above-mentioned appliances in public and commercial sector. Direct load control provides in disposal of the system operator quickly controllable (5…10 MW/min) maneuvering capacity with total amount up to 50 MW.

The main cost item (60–70%) of the direct load control is the investment cost for creating the control system. At that decrease of control and communication equipment prices and thus the marginal cost of direct load control as well can be expected in future.

Implementation of direct load control programs can be dissipated over a long period, comprising, for example, 1000–10,000 new participants per year according to needs and possibilities. In preparatory stage small pilot projects with 10–100 participants can be realized to obtain experience.

Success of load management programs depends on a large extent on the acceptance of customers. Thus it is important to offer sufficient incentives as well as to increase customers' knowledge and attitudes on the entity and overall societal benefits of the management.

And last but not least – it is relevant to underline that load management is fully environmentally adapted technology. Every saved kWh enables to avoid emission of about 1 kg of CO_2, 10 g of fly ash, 9 g of SO_2 and g NO_x and as well to save over 1 kg of the valuable domestic fuel – oil shale.

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