Dynamics of energy-efficient technology for commercial buildings in Sweden: how much can really be achieved and how fast?

Lena A. Christiansson, Lund University
Joel N. Swisher, UNEP Collaborating Centre, Risø National Lab

1. SYNOPSIS

This paper discusses a time-dynamic analysis of the possible effects of governmental and utility-sponsored energy efficiency programs on electric energy use in Swedish commercial buildings.

2. ABSTRACT

This paper discusses the results of a time-dynamic analysis of the possible effects of government and utility-sponsored energy-efficiency programs on electric energy use in Swedish commercial buildings. In the study, which includes efficient lighting, improvements in ventilation, commercial cooling and cooking, we use energy scenarios to analyse how policy measures can effect future energy demand. The focus is on dynamic scenarios of electricity demand and efficiency improvement, based on energy performance standards and utility demand-side management (DSM) investment. The scenarios account for the dynamics of equipment turnover, existing trends in technology, and the distribution of energy efficiency among equipment models on the market.

Many of the technologies are cost-effective and likely to be implemented in time, especially if electricity prices increase. For commercial lighting, the scenarios show that demand-side management (DSM) programs, based on a utility-sponsored shared-savings approach, could keep energy use constant until 2010 despite 45 percent growth in energy services, i.e., growth in lumen-hours per year. Including other commercial end-uses electrical energy use would increase somewhat despite demand-side management (DSM) programs. Energy performance standards are shown to capture many of the least-expensive efficiency options, allowing utilities to focus on other measures, including retrofit measures. Of particular interest are the results indicating important synergies in terms of the timing of the two types of programs. In this paper we show that a combination of utility DSM programs and energy performance standards could keep future energy use low. Other combinations of policies such as energy performance standards and technology procurement programs could also be of great interest.

3. INTRODUCTION

Historically, Swedish energy policy has tried and succeeded to reduce oil use. Since 1970, the use of oil in Swedish buildings has decreased by about two-thirds (Schipper et al. 1993). At the same time overall energy intensities in services and commercial buildings have increased (Schipper et al. 1993). One explanation is that the use of inexpensive electricity has increased. In fact, only Norway has lower non-residential electricity prices among OECD countries (IEA 1992a, Kraftverksföreningen 1991). With sufficient hydro and nuclear capacity, the marginal cost of additional electricity use is low in the short term, even lower than the average prices. As a result, there has been little economic incentive to save electric energy.

However, the possibility of future changes that could increase long-term marginal costs, such as reduced use of nuclear power or possible integration into Europe's power market where electricity costs and prices are higher than in Sweden, suggests the need for stronger policies and programs in regard to electrical energy use in buildings. Future programs and policy measures could include increased energy taxes, energy performance standards, technology procurement programs, and utility demand-side management (DSM) programs. With the exception of strict thermal standards for space heating, Sweden presently does not have strong public policies in regard to energy use in buildings. In addition, studies in Sweden and other countries have identified large available potential for cost-effective energy savings (Fritz et al. 1990). These studies also indicate that electricity customers are not choosing to invest in these measures, despite their economic benefits.

Energy scenario analyses can be used to show how policy measures can contribute to reduced future energy demand. This paper illustrates scenarios for service sector electricity use in Sweden over the next 15-20 years and the effect that government and utility programs could have on future electricity demand. We focus our analysis on lighting but we also consider efficiency improvements for ventilation, cooling, kitchen use etc. We discuss some possible policy programs and concentrate the study on different effects of mandatory efficiency standards and DSM programs on energy consumption. We also present the possible effects of combing two policy programs such as DSM programs and mandatory standards.

4. ENERGY POLICY PROGRAMS

Governments and utilities can introduce various policies to overcome barriers for implementation of energy efficient technologies. One measure would be to include external costs in the energy price, which could be done by applying differentiated taxes on energy sources, and, or by subsidising less polluting energy sources. However, this would not be sufficient to ensure sufficient investment in energy efficient technologies. The government could also encourage improved consumer information and instituting efficiency standards. Examples of the former are on-going or planned appliance performance labelling programs in both North America and Europe. Sweden has today some of the strictest building thermal standards in the world, and as a result Swedish housing is among the most comfortable and energy efficient despite the severe climate. An additional government role is the sponsorship of R&D in energy efficient technologies. Such expenditures only represent about 7 percent of government energy R&D spending in the IEA countries. This is equivalent to a tenth of what is allocated to coal and nuclear energy R&D (IEA 1992b).

Other governmental policy measures that further enhance the rate at which energy efficient equipment is introduced to the market include stimulating product demand via procurement, accelerating technology development and demonstration, and encouraging utility demand side management (DSM) programs. DSM programs have been introduced by many electric utilities, mostly in the United States and Canada. These DSM programs typically involve dissemination of information, financial incentives through rebates or loans, direct installation of efficient equipment, and bidding programs where utilities request proposals from outside parties to reduce customer demand.

4.1. Implementation of Energy Performance Standards

Energy performance standards, applied to specific types of equipment or based on aggregate building performance levels, provide one policy mechanism for capturing a large share of the cost effective measures. The advantages of standards is that they contribute to conserve energy in every part of the sector, even in buildings where owners and contractors in general do not take advantage of efficiency opportunities. For example, landlords and builders who are not paying for the electricity very seldom care about the equipment installed, and for that reason energy-inefficient equipment is installed to minimize first cost. While standards alone do not ensure that the societally optimal level of efficiency will be obtained, additional efforts such as technology procurement and utility programs can contribute to more efficient energy use.

There are two basic types of performance standard, as mentioned before: component standards that govern the efficiency of various types of equipment, and systems standards that govern the overall energy efficiency of a building or functional areas within a building. Component standards are advantageous for improving the energy performance of equipment replacements in existing buildings (Atkinson et al. 1992). While it would be difficult to require that existing buildings meet a system performance standard any time old existing equipment is replaced, component standards can be used to ensure that the replacement equipment is relatively efficient. In new buildings, however, system performance standards are appropriate to allow designers flexibility to exploit system interactions that provide better overall energy efficiency with lower cost and greater comfort than simply by following component standards. Unlike component standards, system performance standards also guard against wasteful energy consumption, even with relatively efficient components, resulting from unnecessarily high design-levels for illuminance and other energy services.

In this paper energy performance standards for lighting technologies are analysed. The assumed component standards include combined fluorescent lamp and ballast performance of 80 lumen/watt or more, luminaire efficiency of 70 percent or more, and high-intensity discharge (HID) lamp efficacy of 90 lumen/watt or more. These levels can be met or exceeded with off-the-shelf equipment, including 32 W fluorescent tubes with electronic ballasts, specular-reflector luminaries, and metal halide or high-pressure sodium HID lamps (Geller and Nadel 1992, Atkinson et al. 1992). The system performance standards assumed for new buildings are similar to those required in California, corrected for somewhat lower illuminance levels in Sweden (California Energy Commission 1992). These standards can be based on either room-usage type or building type. The standard levels assumed here are based on room-usage type, but table 1 also shows the corresponding levels based on building type. Also, table 1 shows the system performance levels that would be achieved by complying with the component standards for the same room and building types.

Table 1. Maximum Lighting Power Densities for System Performance Standards (W/m^2)

Room Type:	System standard	Component standards' effect	Building Type:	System standard	Component standards' effect
Office rooms	12	14			
Office corridors	6	7	Office buildings	10	12
School rooms	12	14	Banks/insurance	11	13
School corridors	8	15	School buildings	11	13
Health care rooms	8	10	Health/daycare	9	11
Treatment rooms	12	13			
Health care corridors	6	7			
Retail stores	14	15	Retail buildings	12	14
Food store	14	18	Supermarkets	12	14
Hotel/restaurants	10	14	Hotel/restaurant buildings	10	14
Library/meeting rooms	14	28	Libraries/Auditoriums	12	19
Sport facilities (indoor)	14	19	Sports buildings	12	16
Warehouses (indoor)	8	9	Warehouse buildings	9	10
Workshops/industrial (indoor)	8	13	Workshops/indust. blgd.	9	12

4.2. Implementation of Demand Side Management (DSM) Programs

Utility demand-side management (DSM) programs that combine information and financial incentives, or even direct installation of efficiency measures, can bring the economic evaluation of energy efficiency onto a more equal basis with supply expansion (NWPPC 1992). DSM programs make it possible for utilities to influence their customers load profile to better match their production capacity, mostly by reducing peak demands. In general, DSM programs increase customer satisfaction, and they can reduce the environmental impact of power plant siting and use (Nadel 1992). It is unlikely, however, that the future role of DSM in Sweden will resemble that of the regulated North American utilities, as the entire Swedish utility industry is in the early stages of a restructuring process toward greater competition and less government control. A more likely model is that Swedish utilities will begin using DSM as a tool to defend their market share against new competition by marketing their non-residential service more efficient and economical (via lower bills, not lower rates) (Swisher and Hedenström 1993).

In the scenarios discussed below, we consider the effect of DSM for the total service sector. For lighting technology we consider DSM alone and with mandatory energy performance standards already in place, in which case the DSM programs would be used to exceed the mandatory performance levels. The utility programs analyzed here mostly employ a shared-savings approach, where the utility or a third-party intermediary pays an incentive for the customer to invest in an energy-efficiency measure, in exchange for a fraction of the energy savings which can be paid via the electricity bill.

The relative size of the incentive payment and the shared-savings payment can be tailored to meet each party's economic criteria. For a given shared-savings fraction, e.g. 50 percent, there is a minimum incentive required for the customer's participation, depending on the inherent cost-effectiveness of the measure, at the expense of the utility's return. We assume an 80 percent incentive, which means that the customer's payback is shortened by 60 percent (20 percent payment for 50 percent savings) and the utility's is increased by 60 percent (80 percent payment for 50 percent savings). For a measure with a customer payback of 1 year, the utility payback is 4 years, in which case both parties are likely to accept the measure. Although only the simple payback is used in the analysis to asses each party's economic criteria, full life-cycle costs are used to calculate program performance based on benefit-cost ratios and cost of saved energy. The life-cycle costs, including utility transaction costs, depend on the discount rate and on the lifetime of the DSM measure.

4.3. Implementation of Technology Procurement

An innovative energy-efficiency policy intervention is public technology procurement which has been developed in Sweden by the Board for Industrial and Technology Development. This process combines government incentives with guaranteed orders from organized buying groups (such as apartment managers) in a competitive solicitation for improved energy efficient products (Westling 1991). Manufacturers are invited to enter prototype models with certain features, including a specified minimum energy efficiency, and the entries are judged according to their efficiency and how well they satisfy the other requirements (Nilsson 1992). The winner(s) receive incentive payments and a guaranteed initial order sufficient to begin production of the new model.

This process was successfully completed in 1991 for fridge-freezers, with the winning model's energy use 30 percent below the previous best available and 50 percent below the average in the market (NUTEK 1992). Although the winning model entered the market with nearly a 50 percent price premium, within one year the price premium was reduced to about 10 percent and a competing firm offered a new model with energy use comparable to the winner and a price close to other models on the market (NUTEK 1992, NUTEK 1993, Lewald and Bowie 1993). The procurement process has also been applied in Sweden to high-performance windows, high-frequency lighting ballasts, computer displays that turn off automatically, washing machines, and most recently ventilation equipment.

In this paper no consideration is taken of technology procurement and its effect on future energy demand in the service sector. However, the effect of technology procurement in the scenarios will be accelerated energy-efficiency gains caused by raised efficiency of the best-available models early-on. (Swisher 1994) At present a research co-operation program between NUTEK and the Department of Energy and Environmental Studies, Lund University, is evaluating technology procurement programs and their effect on future energy demand in addition to standards and DSM program scenarios.

5. SCENARIO ANALYSIS

This analysis of non-residential electricity is based on technical information from "Uppdrag 2000," (project 2000) a field study of energy efficiency options by Vattenfall AB, Sweden's largest electric generator and wholesaler and formerly the national power board. The study produced the first detailed statistical picture of energy in the Swedish service sector and evaluated the potential cost and performance of a wide range of energy-saving measures (Hedenström et al. 1992). The STIL ("statistisk studie i lokaler" - statistical study in commercial premises) survey data conducted as part of Uppdrag 2000 covered commercial and public service customers with annual consumption of 20 MWh or more. To these results we add end-use estimates for "other services:" small premises, public works, light industrial buildings, public lighting, and the non-residential shares of large multi-family housing developments.

The Uppdrag 2000 results suggest savings potential in the service sector, from a viewpoint of business economics, of about 10-15 percent based on retrofit measures that could be implemented immediately, while other studies estimate a savings potential of over 50 percent, compared to present technology, by 2010 (Hedenström 1991, Fritz et al. 1990). While the achievable energy efficiency potential is not as great as studies of technical potential suggest, Vattenfall's results are an underestimate because they ignore the longer-term efficiency potential in new buildings and replacement equipment. Instead scenarios for future electricity use must take into account diffusion of new technology over the years. In this analyses we say that efficient new and replacement equipment can be installed up to a maximum penetration rate, and all retrofit measures have a similar maximum rate at which they can approach the full penetration level, which must be corrected for the annual turnover in building and equipment stock. These rates depend on the maturity of the market and the level of program activity.

In this study we use the Compass computer model from Synergic Resources Corp, modified for Vattenfall and Sweden, to conduct the detailed accounting and market penetration analysis (SRC 1991). We assume that the fraction of customers who will adopt a given efficiency measure depends on its economic return, measured by the simple payback time. This formulation can be used to drive the market acceptance analysis in the Compass program. We use it to explore the effects of energy efficiency standards and changes in energy prices. According to the Uppdrag 2000 results, the longest payback that a commercial customer will accept is about 5 years. At the same time, one can identify substantial energy-saving potential that is not being exploited despite a payback of only about 1,5 years. We use a payback-acceptance function where 20 percent of customers adopt measures with a 5-year payback, 50 percent accept 3 years and 80 percent accept 1,5 years (Hedenström 1991).

5.1. Lighting Technology Analysis

The use of electrical lighting has increased over time and the design and efficiency of lighting systems have changed. Today compact fluorescent lamps (CFLs), new energy-saving fluorescent lamps, high pressure sodium and metal halide HID lamps offer energy efficient alternatives to older types of lamps. For example, when a conventional incandescent lamp is replaced by a compact fluorescent lamp (CFL), 70-80 percent less electricity is used. However, maximising the energy and cost savings of efficient lighting designs requires a system approach which, in addition to the improved lamp, includes the ballast, lighting fixtures, controls and operational parameters. Electronic lighting controls, such as time-scheduling, day-light dimmers, or occupancy sensors can ensure that light is only provided when and where it is needed.

The main focus for lighting technology in this paper is on efficient technologies including improved lamps, ballasts, luminaries, controls and system designs to better exploit natural daylight and task lighting. We rely primarily on the STIL survey, which sampled over 900 commercial buildings, for the statistical basis of our end-use analysis. The types of customers, buildings, rooms, and technologies vary widely, and we try to strike a balance between the rigor and detail of the analysis and the need for simplicity and transparency. For each of 14 service-sector room-usage types, we choose from a menu of energy-efficient lighting technologies to identify improvements that are likely to be feasible and effective (table 2). The measures shown in table 2 are all based on technology that is commercially available today. Although many of these measures represent considerable efficiency gains compared to present practice, they are by no means the best that can be achieved. Thus, to the extent that even more efficient technology can be introduced during the time horizon of our analysis, our results can be considered somewhat conservative in regard to technical potential. In the analysis it is assumed that the total luminous flux (lighted area times average illuminance) grows at 2,3 percent per year, consistent with recent electric forecasts for the Swedish service sector (Kraftsam 1990).

Table 2. Performance and Cost of Energy Efficient Lighting Improvements by Room Type for Service-sector

	Base 1989 Energy use kWh/m²	Measure	Energy efficiency technology	Improvement Energy use kWh/m²	Difference %	Cost ECU/kWh
Office rooms	47	retrofit	EFLs, reflectors	23	51	0.08
	31	new	EFLs, reflectors, HFBs	19	39	0.02
	31	new	EFLs, reflectors, HFBs, occ'y	15	52	0.09
Office corridors	49	retrofit	EFLs, reflectors	34	31	0.09
	49	new	EFLs, reflectors, HFBs	24	51	-0.03
School rooms	39	retrofit	EFLs, reflectors	19	51	0.09
	26	new	EFLs, reflectors, HFBs	15	42	0.02
	26	new	EFLs, reflectors, HFBs, occ'y	12	54	0.02
School corridors	28	new	EFLs HFBs, CFLs	9	68	-0.03
Health care rooms	26	new	EFLs HFBs, CFLs	12	54	-0.05
Treatment rooms	50	new	EFLs HFBs	39	22	0.04
Health care corridors	32	retrofit	EFLs, reflectors	23	28	0.11
	32	new	EFLs, reflectors, HFBs	16	50	-0.03
Retail stores	73	retrofit	EFLs, reflectors	52	29	0.07
	73	new	EFLs, reflectors, HFBs	40	45	0.00
Food stores	97	retrofit	EFLs, reflectors	63	35	0.08
	97	new	EFLs, reflectors, HFBs	48	52	0.02
Hotel/restaurants	34	new	EFLs HFBs, CFLs	11	68	-0.04
Library/meeting rooms	24	new	EFLs HFBs, CFLs	7	71	0.00
Sport facilities	49	new	EFLs, HFBs, Hg+HPS	24	51	-0.02
Warehouses	26	retrofit	EFLs, HFBs, HPS+MHL	16	38	0.11
	26	new	EFLs, HFBs, occ'y, HPS+MHL	11	58	0.02
Workshops/industrial	42	new	EFLs, HFBs, HPS+MHL	24	43	0.00

Notes: Office rooms and school rooms are divided into older buildings, built before 1980, and newer buildings, built after 1980. It is only older buildings, which have higher energy use per square meter than the average, that are considered for retrofits. EFLs: Efficient Fluorescent Lights, reflectors: Imaging-reflector luminaries, HFBs: High Frequency Electronic Ballasts, occ'y: Occupancy Sensors, CFLs: Compact Fluorescent Lamps (replace incandescents),Hg+HPS: Mercury Vapour Lamps and High Pressure Sodium Lamps (replace fluorescents), HPS+MHL: High Pressure Sodium Lamps and Metal Halide Lamps (replace mercury vapour).
Additional cost and performance data are provided by Wabema, a Swedish lighting consultant.

5.2. Ventilation Technology Analysis

In contrast to lighting systems, ventilation systems are more diverse and energy efficiency measures differ more from one system to another. However, efficiency measures are of great importance because electricity use for ventilation has increased considerably during the last decades, as the need for mechanical ventilation has increased due to many factors, e.g. lower ceiling heights in residential buildings, better insulated and more airtight buildings, more excess heat from office equipment, more pollutant sources, etc. To reduce electricity use for ventilation, the need for ventilation could be reduced, i.e. through measures outside the ventilation system. With shading of windows to reduce solar heat gains, more efficient lighting systems, more efficient office equipment etc. excess heat can be reduced and hence the need for cooling-air flow.

This study concentrates on the possibilities to improve ventilation systems by improvement via technological change, and the important element is the overall efficiency. The overall efficiencies in the system vary from about 10 percent to 50 percent, with an average value of approximately 30 percent (Mehlsen 1989). When installing a ventilation system, the need of flexibility and low initial costs are often at a premium, while little incentive exists for minimizing long-term energy costs. This situation often results in a badly operating system, which furthermore suffers from deficient maintenance and poor heat-recovery. Specific fan power (SFPI) in Sweden is estimated to be between 0,5-1 kW/m3/s with good design practice, but the average SPFI measured by different studies indicate that it is 1,5 kW/m3/s (Nilsson 1993).

Efficiency can be improved by using variable-air volume (VAV) control instead of constant-volume systems, which are present in more than 90 percent of Swedish commercial buildings. VAV systems are most efficient when run by variable-speed drives (VSD), although VSDs have little effect in constant-volume systems. The VAV systems can either be very complex with individual controllers in almost every room in a building, or simpler with only a few controllers regulated by the outdoor temperature, for example. The air flow can also be regulated by the use of time controllers or two-speed motors, which are used in 36 and 30 percent, respectively, of Swedish buildings. (Hedenström et al. 1992) The use of VAV can reduce cooling loads by about 20 percent in new buildings, and by about 10 percent in existing buildings, although at higher cost (NWPPC 1992). However, the installation of two-speed motors in CAV systems can result in larger energy savings. (Jagemar 1994)

In addition, ventilation energy efficiency can be improved by a number of small measures, including more efficient fans and motors and, in new and replacement systems, proper sizing of air-handlers and ducts (Larson and Nilsson 1991). In Sweden, a difference between standard and energy-efficient motors of about 3-10 percentage units do exist for motors smaller than approximately 11 kW. The opportunity to install a fan with improved efficiency is to use a fan with backward curved blades (B-fan) instead of a fan with forward curved blades (F-fan).

Due to the many uncertainties and the wide range of energy-efficiency options for ventilation systems, we estimate relatively modest savings of about 10 percent under a DSM program, although these uncertainties make it difficult to analyze the different building types in detail.

5.3. Other End-Use Analysis

Regarding other end-uses within the commercial sector, this analyses deals with refrigeration, cooling, cooking and office equipment. Space heating and non-building end-uses such as transport are excluded.

For refrigeration in supermarkets and other stores, energy efficiency in new and replacement compressor units can be improved by about 20 percent using, for example, floating head-pressure control (NWPPC 1992). Retrofit measures include adding doors and covers to open refrigerator and freezer covers (Miller et al. 1989). Another cooling end-use that can be made more efficient is ice-making for winter-sports facilities. Uppdrag 2000 case studies show 60 percent savings in ice rinks through improved control and heat recovery (Hedenström et al. 1992).

Air-conditioning energy efficiency can be influenced by cooling equipment efficiency, building-envelope heat transmission, and heat loads from other equipment such as lighting. Because building envelopes in Sweden are required to be relatively tight under the building standards, most of the available options for cooling energy-efficiency improvements are related to equipment efficiency and reductions in lighting loads, the latter of which are considered in detail above (Hedenström et al. 1992).

In large restaurants and hotels, cooking energy can be reduced up to 70 percent, using electronically controlled ovens and inductive stoves. These technologies, which substantially reduce stand-by heat losses from cooking equipment, were demonstrated as part of the Uppdrag 2000 case studies (Hedenström et al. 1992). It was observed that the large reductions in waste heat can also make the kitchen working environment more comfortable.

There are also large potential energy-efficiency improvements in computers and other office equipment. Sweden has recently conducted a successful public technology procurement for automatic shut-off computer monitors (Lewald and Bowie 1993) This technology and other energy-efficient office-equipment products are expected to gain a large market share in the next generations of office-equipment technology (Dandridge et al. 1993). We therefore estimate that the reference scenario includes energy savings of slightly more than 50 percent compared to current equipment models.

6. RESULTS OF THE SCENARIOS

To analyse the introduction of efficient technology in the service sector we develop dynamic scenarios of electricity demand and efficiency improvement, based on various levels and timing of policy programs. We examine the achievable potential, which over time increases as new energy-saving opportunities appear in new and renovated buildings and equipment that is replaced by newer models. The rate of energy-efficiency implementation is limited, however, by the rate of turnover of existing buildings and equipment, and it is subject to constraints on administrative costs and market penetration rates. The market adoption of the efficiency measures under different programs and incentives is especially complex. Some measures will be implemented without special programs or policies; i.e. even a "business as usual" reference case includes some energy savings.

In the analyses we consider four scenarios without DSM implementation and three scenarios with DSM. The non-DSM cases include two reference cases and a frozen new-model efficiency scenario (A), representing a case where all new and replacement equipment has the same energy-efficiency as 1990 average new models. The first reference case (B) has stable prices until after the year 2000, when prices increase by about 25 percent due to supply constraints and/or integration with the European power market. The second reference case (C) assumes a further 25 percent increase. We also consider a case with mandatory energy performance standards (D) for lighting technology in place in 1999. The DSM cases include one case with immediate implementation of a shared-savings incentive program (E), one case with immediate implementation of a shared-savings incentives program but delayed introduction (from year 2000) of retrofit programs (F), and one case with the same the shared-savings program with delayed retrofits but based on the performance standards already being in place (G).

Scenarios for the year-by-year energy consumption for lighting in Swedish service sector until 2010 are shown in figure 1. The reference scenario (B) shows significant energy savings, over 10 percent in 2010 compared to the constant-efficiency case. However, total consumption continues to increase despite the assumption of higher electricity prices. Even a 50 percent increase in electricity prices does not have a major impact on reducing consumption growth, as shown by scenario C in figure 1. This result is consistent with other studies that have reported low customer response to electric price increases, because of various information and institutional barriers (Levin Kruse 1991, Nielsen et al. 1992). The fact that significant savings would likely be achieved without the DSM programs means that there will be customers who take advantage of utility-sponsored incentives, even though they would have invested in efficiency measures without the incentives, i.e. there will be "free riders."

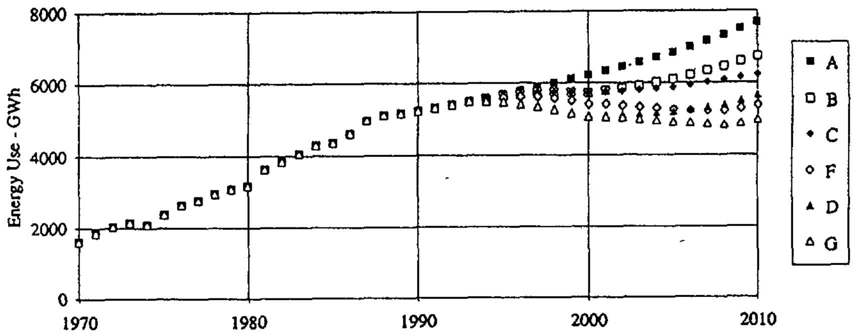

Figure 1. Service-Sector Lighting. The scenarios are: A) all new and replacement equipment ontinues to have the same energy-efficiency as 1990 models; B) reference case, with efficiency improvements implemented according to present trends and investment payback criteria, 25 percent electric price increase; C) reference case, with 50 percent electric price increase; D) mandatory energy performance standards for new and replacement equipment in full effect in 1999; F) full implementation of utility-sponsored DSM incentives, with programs for new and replacement equipment beginning in 1994 and retrofit programs delayed until 2000; G) full implementation of DSM incentives, in addition to full standards.

The energy savings due to energy standards, as shown in scenario D, are about 25 percent in 2010, compared to the energy consumption that would occur with constant 1990 efficiency, or about 15 percent compared to the reference case. In the absence of standards, the full DSM program in the service sector, shown scenario F, could save enough energy to keep total lighting consumption in 2010 at approximately the 1990 level, despite 45 percent growth in services. With standards in place, the opportunity for DSM measures are reduced, but some additional savings can be achieved beyond the baseline efficiency set by standards. Scenario G indicates that lighting consumption in 2010 can be below the level of 1990.

When constructing the other scenarios for the service sector we do not consider these end-uses in the detail with which we have treated the lighting end-uses. Nevertheless, we apply the same methods and assumptions described above for the technology analysis and DSM program analysis. Considering ventilation, cooling, and kitchen end-uses, the reference scenario includes almost 15 percent savings compared to the constant-efficiency case. The full DSM program (scenario E) achieves reductions in energy use to near the 1990 level, see figure 2. Delaying the retrofit

DSM measures (Scenario F) results in energy consumption almost the same as the reference case until 2000, but energy consumption is later decreased to nearly the same level as the full DSM case.

Cost-effective energy-efficiency improvements in computers and other office equipment are assumed to be captured in the reference scenario, which includes energy savings of slightly more than 50 percent compared to current equipment models. These savings, including new and available technologies, can take place quickly, because of the fast turnover of electronic equipment. The improvements are driven by the rapid technical advances in this area, leaving little room for DSM programs to further accelerate the rate of efficiency improvement.

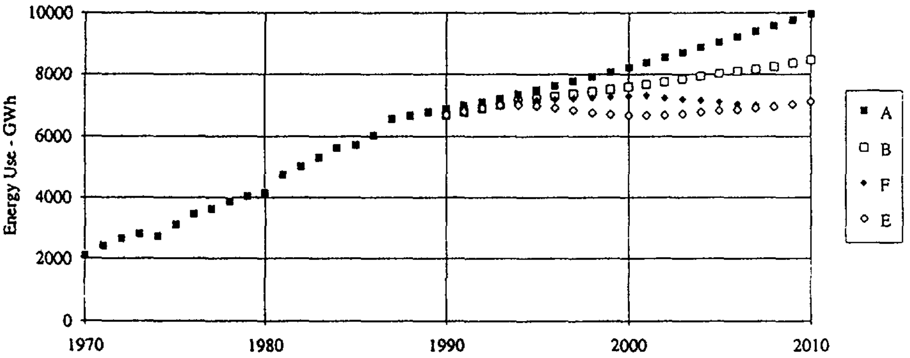

Figure 2. Ventilation, Cooling and Kitchen End-Uses. The scenarios are: A) all new and replacement equipment continues to have the same energy-efficiency as 1990 models; B) reference case, with efficiency improvements implemented according to present trends and investment payback criteria, 25 percent electric price increase; E) full implementation of utility-sponsored DSM incentives, with all programs beginning in 1994; F) full implementation of DSM incentives, with programs for new and replacement equipment beginning in 1994 and retrofit programs delayed until 2000.

The results of the scenarios for the different end-uses in the service sector are summarized in table 3. In the reference scenario (B), energy use grows at slightly more than 1 percent per year, less than half the rate of growth in services. The full DSM programs (scenarios E/F), including lighting and other service-sector end-uses, can reduce this growth in total energy consumption by more than half, with the result that 2010 consumption is about 5 percent higher than the present level. Energy performance standards for lighting only (scenario D) can provide about half of these savings, since lighting is the largest end-use. The combination of lighting standards and DSM programs for lighting and other end-uses (scenario G) could further reduce total lighting energy consumption in 2010 to less than 10 percent above the present level.

Table 3. Summary of Scenarios for Swedish Service-Sector Energy Use (TWh)

	Lighting (STIL survey)	Other lighting	Cooling/ kitchen	Ventilation	Office equipment	Other uses	Total services
1989 Consumption	5,0	2,6	4,1	2,7	1,6	1,1	17,1
2010:							
A. Constant efficiency	7,7	3,7	5,5	4,5	3,0	2,4	26,7
B. Reference case	6,8	3,0	4,7	4,0	1,7	2,4	22,5
D. Mandatory standards	5,7	2,6	4,7	4,0	1,7	2,4	21,0
E./F.Full DSM case	5,3	3,0	3,7	3,6	1,7	2,4	19,5
H. Standards + DSM	4,9	2,6	3,7	3,6	1,7	2,4	18,8

Note: Energy performance standards apply to lighting end-uses only. Total consumption values exclude space heating and non-building end-uses such as water works, transport, etc.

Thus, it appears that aggressive energy-efficiency programs in the service sector could essentially stop electricity consumption growth caused by growing demand for energy services. Most of the remaining energy consumption growth in scenario G is in miscellaneous end-uses, for which we have not included energy-efficiency improvements. It is likely, however, that at least some of these end-uses offer inexpensive efficiency opportunities that could be captured through DSM, standards or other programs.

An additional effect of electricity end-use efficiency improvements is that they can influence the demand for space heating energy, only a fraction of which is provided by electricity in service-sector buildings. Thus, saving electricity can increase or decrease the consumption of other fuels that are used for space heating. We evaluated this effect, based on the results of the case studies conducted by Vattenfall under Uppdrag 2000. Their results show that one kWh saved in lighting or office equipment tends to increase heating fuel demand by 0,7 kWh; while one kWh saved in refrigeration tends to save 1,5 kWh of heating fuel; and one kWh saved in ventilation tends to save about 4 kWh of heating fuel. (Hedenström et al. 1992). Other electric end-uses have a neutral effect on heating. The results of applying these factors to the results of our DSM scenarios are that the overall effect of the electric efficiency improvements on heating fuel demand is negligible. The increased demands in some buildings are compensated by extra savings in others. There is of course some effect on the energy and cost savings in individual buildings, but the economic effect is mitigated by the fact that heating fuels and district heating are much less expensive than electric energy.

7. CONCLUSION: TIMING OF ENERGY EFFICIENCY PROGRAMS

A comparison of the scenarios shows that government policy measures and utility programs can affect and decrease future energy demand. At present, there is not a strong motivation to implement energy-saving measures, due to the continuing surplus of electric supply in Sweden. As a result, the strategy of Vattenfall in initiating Uppdrag 2000 is not presently being carried out. Presumably, the retrofit efficiency measures identified under Uppdrag 2000 could be implemented later when supply constraints appear, or to defend the utility's market under the threat of new supply competition. However, energy-efficiency options in today's new and replacement equipment present one-time "lost opportunity" resources. The later the efficiency programs are carried out, the more potential will be lost and the longer it will take to decrease energy demand, due to the dynamics of the technology implementation. To speed up the effect of efficiency measures, policy programs can be combined. In this paper we analysed energy standards in combination with DSM programs. However other combinations of interest include energy standards and technology procurement programs, where standards eliminate technologies with low efficiency technologies on the market and technology procurement programs introduce new efficient alternatives.

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