The Costs and Benefits of Policies for Efficient Use of Electricity:Improved Estimates of per-kWh Costs, and Potential Cumulative Cost Savings for Western European Electricity Users

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Synopsis

This paper finds that the full implementation of electrical efficiency resources in Western Europe over the next 30 years would save electricity users 16-40 percent of projected year 2020 electricity bills, or 150-300 billion ECU on a cumulative, net present value basis.

Abstract

This paper finds that most past studies significantly understate the economic benefits of electrical efficiency improvements, despite the fact that most such studies have identified significant cost-effective demand-side efficiency resources. Using a more comprehensive costing methodology, we estimate that the full implementation of electrical efficiency resources in Western Europe over the next 30 years would save electricity users 16-40 percent of projected year 2020 electricity bills, or 150-300 billion ECU on a cumulative, net present value basis.
The research summarized in this paper distinguishes itself from previous analyses of the potential and cost-effectiveness of electrical efficiency improvements in several respects. First, electrical efficiency is analyzed from a national policy perspective rather than from the perspective of individual investors or utilities. Correspondingly, energy efficiency is treated as a resource whose costs and market deployment over time can be shaped by policy action.

Second, our analysis goes beyond the purely engineering-economic framework of many previous studies. To arrive at realistic cost estimates for the purpose of policy decisions, we integrate the prospective view of technology analysis with the retrospective view of program evaluation and market transformation research.

Third, the cost of energy efficiency resources is based on a more rigorous definition and comprehensive treatment of cost components than found in most previous studies. In particular, we take into account field-measured savings, explicitly incorporate administrative and other indirect program costs, and include foreseeable feedback effects of policies on technology prices. Estimates for the latter are taken from recent evaluation research on energy efficiency standards and market transformation programs. All told, 21 distinct factors are considered in calculating the cost of energy efficiency.

Fourth, we explicitly incorporate existing data uncertainties on technology and program costs, performance, and policy feedbacks. Instead of presenting only point values for the cost of saved electricity, we derive uncertainty bands, and correlate the width of these bands with policy choices.
Finally, the potential economic and environmental benefits of implementing electrical efficiency resources are estimated on the basis of an integrated least-cost analysis that takes into account interactions with the supply-side.

1. Introduction

1.1. scope

The following document summarizes research on electrical energy efficiency resources in a five-country region of Western Europe: France, Germany, Italy, the Netherlands, and the UK. Based on pre-1990 borders for Germany, these countries had a population of about 250 million people, comparable to that of the U.S., and accounted for roughly three quarters of electricity use in the European Union (EU). Our analysis covers electricity use in all sectors of the economy, disaggregated into more than 90 end-uses and 280 efficiency techniques.

1.2. Methodology

The research summarized here distinguishes itself from previous studies on the costs and resource potential of electrical efficiency in several respects. First, electrical efficiency is analyzed from a national policy perspective rather than from the perspective of individual investors or utilities. Correspondingly, energy efficiency is treated as a resource whose costs and market deployment over time can be shaped by policy action.

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Finally, the potential economic and environmental benefits of implementing electrical efficiency resources are estimated on the basis of an integrated least-cost analysis that takes into account interactions with the supply-side. In this integrated analysis, we acknowledge legitimate differences of opinion regarding the achievable speed and effectiveness of policy action. Results are calculated for different scenarios in which varying fractions of the total demand-side efficiency resource are implemented (see also Part 3A of the IPSEP study). The following pages briefly summarize each of these major elements.

2. Technical resource potential

2.1. Reference scenario

Our reference scenario for the EU-5 region is based on the extrapolated projections of the European Commission in its study on Energy for the Next Century.

2.1.1 Growth of energy services

Electrical energy services (ownership and operation of appliances, lighting, machinery, computers, etc.) more than double between 1985 and 2020.

This projection includes strong electrification trends in industrial processes, and continued expansion of electricity use in low-temperature applications where its use may be economically inefficient. Allowance is also made for the introduction of electric vehicles.

2.2 electricity demand

In the reference scenario based on the (extrapolated) DGXVII analysis, electricity demand grows somewhat slower than energy services, due to autonomous trends in energy efficiency. Based on an average autonomous improvement of 15 percent, final electricity demand in 2020 is 79 percent higher than in 1985. Significantly diverging values apply to individual countries, with France and Germany representing the high and low ends.

2.3 Results: Technical potential of electrical energy efficiency improvements

On average, the efficiency of Western Europe's final electricity use can be increased by a factor of 2.5 relative to the 1985 base year. More than 80 percent of this efficiency potential stems from already commercially available technologies, the rest from demonstrated near-commercial technologies.

At base year levels of electricity services, Western Europe's power requirements could be cut by about 60 percent if these demand-side efficiency resources were fully implemented.

2.4 Results: electricity demand in policy scenarios

Given that most electricity-using plant and equipment has an economic life of 10-25 years, Western Europe's capital stocks could be fully converted to state-of-the-art efficiency levels within less than three decades. If fully exploited, electricity demand in 2020 would be as follows:

- no higher than in 1985 if considering only currently commercial technologies (a demand-side resource of 865 TWh); 25 percent lower than in 1995.
- 15 percent lower than in 1985 if accounting for both currently commercial and near-commercial advanced technologies (a demand-side resource of 1010 TWh); 36 percent lower than in 1995.
- 20 percent or more below 1985 levels if electric space heating and electric water heating were discontinued in economically inefficient applications (a demand-side resource of at least 1075 TWh); 40 percent lower than in 1995.

3. The real cost of conserved electricity

3.1 Improvements to engineering economics

To address the shortcomings of past cost assessments, we introduce in our study a new analytic framework. This framework integrates conventional engineering-economic analysis with the findings from program evaluation and market transformation research. It also includes an economic rather than merely financial perspective on energy efficiency benefits and costs and is specifically geared toward policy analysis.

Starting from conventional cost calculations, we implement this framework in the form of 21 cost factors. For each of these factors, we review the range of plausible values suggested by recent empirical data. Greatly improved data have become available from the extensive body of impact and process evaluation studies spawned by the rise in government and utility-sponsored energy efficiency incentive programs in the U.S. and elsewhere. These studies rely on actual field experience with real users of energy-efficient equipment, and verify predicted energy savings through ex post measurements. They also permit more precise quantifications of utility program administration costs, free rider and free driver effects, and the costs of verifying savings.

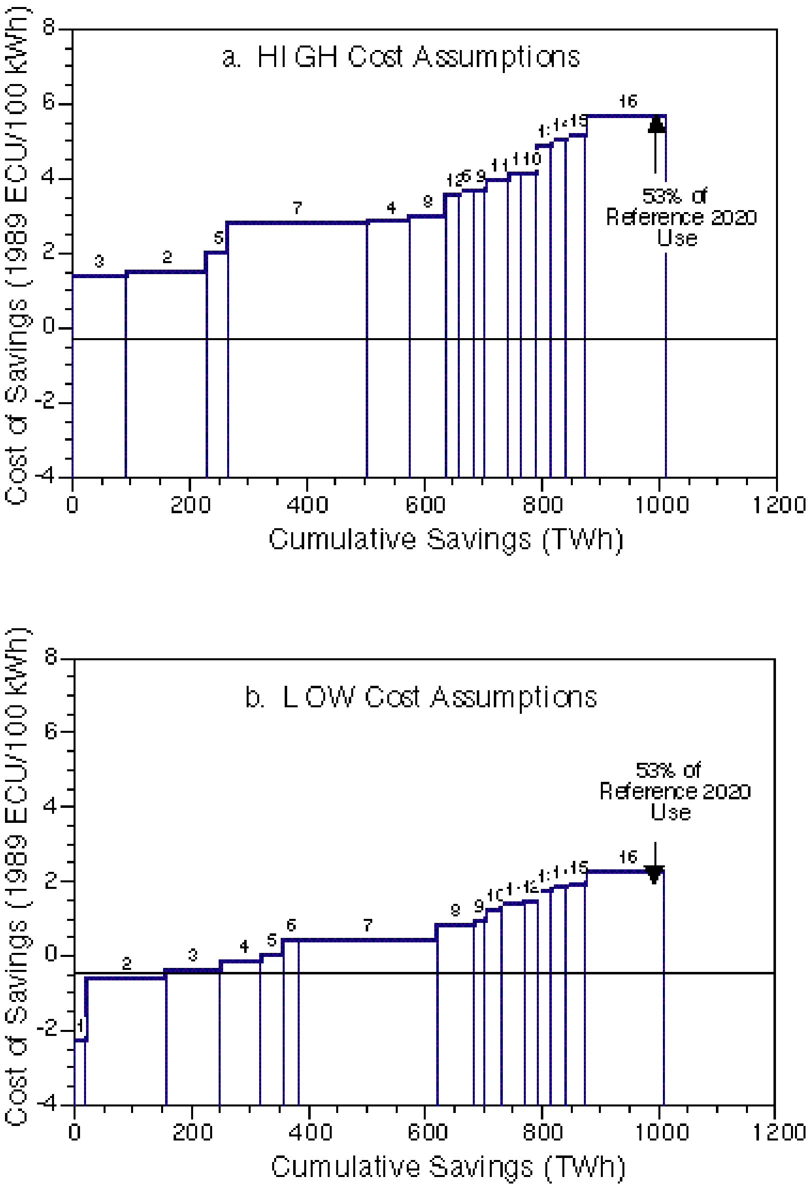
We apply these data in a deliberately conservative fashion, i.e., in a manner that tends to overstate economic costs. To account for uncertainties, observable cost trends, and policy feedbacks (see below for further explanation), we develop high/low ranges or conservative upper limits for all key factors affecting energy efficiency costs. These procedures ensure that our efficiency cost estimates represent plausible extrapolations of demonstrated field experience. In combination with our comprehensive checklist of cost factors, these quantitative estimates provide a transparent template against which other cost-effectiveness assessments can be evaluated.

3.2 Total unit cost of conserved electricity

Figure 3-2 shows the supply curve of electricity savings in Western Europe, aggregated into 16 major categories and assuming, respectively, high and low costs. The real discount rate is 5 percent. As the figures show, the range of CCEs across all end-uses and sectors is considerable.

3.2.1 High estimate

Our high estimates reflect, in stylized fashion, a world in which no large-scale policy efforts are made to implement energy efficiency standards and utility DSM programs. Government initiatives are limited to information and labeling programs, and to selective voluntary agreements with manufacturers. What efficiency investments beyond market trends are triggered by these weak policies are pursued mainly through shared savings contracts supplied by utility-owned or independent energy services companies. As a result, no systematic mobilization of demand-side resources occurs. The cost-reducing feedback effects that broad policy programs would have generated remain largely unrealized.



Source: IPSEP 1996

Figure 3-2 a/b: Supply curves of electricity savings for the EU-5 region in 2020

To define an upper-limit case for costs, this policy environment is matched with assumptions of high technology costs (reflecting the suboptimal technology packages that result from cream-skimming and other dynamics characterizing incomplete and inefficient energy services markets), low annual operating hours where these are uncertain; and/or omission of opportunities for secondary capital cost savings in related end-use equipment; high space heating requirements for the replacement of lost internal heat gains in buildings; low credits for avoided transmission and distribution (T&D) costs; and no geographical targeting of these programs that could produce further T&D cost savings.

Figure 3-2a shows the corresponding supply curve. With high cost assumptions, the range of costs for saved electricity is 0.014-0.057 ECU/kWh. The weighted average is 0.032 ECU/kWh (constant 1989 ECU).

3.2.2 Low estimate

In our low estimates, we simulate a world in which effective voluntary and mandated standards and well-monitored DSM incentive programs succeed in shifting end-use investments to best technology. Utility DSM programs are conducted under suitable regulatory mandates and financed through rates (franchised monopoly structure in the distribution industry) or through a non-bypassable energy efficiency fee (retail competition). In the wake of policy goals and new regulatory mandates for the utility distribution sector, the independent energy service industry also grows to become larger and more effective.

The resulting market transformation effects reduce the prices of energy-efficient technologies by more than a third relative to the high estimate. Lower mark-ups, technological learning and economies of scale in production and distribution, less cream-skimming, and better optimized packages of measures explain these price reductions. In addition, policy feedbacks cut program administration costs in half through learning effects, economies of scale, and through accelerated innovation in program designs.

These price-reducing policy effects are matched with more favorable assumptions for various uncertain factors. Greater recognition is given to upstream and downstream capital cost savings. Space heating requirements to replace lost internal gains are lower, while the estimated average equipment operating hours are higher. Finally, a higher credit is given for avoided transmission and distribution costs, partly reflecting geographically targeted DSM programs.

Figure 3-2b shows the corresponding supply curve. With low cost assumptions, CCEs range from a negative net cost[1] of -0.02 ECU/kWh for a package of water heating efficiency measures to 0.023 ECU/kWh for the most expensive of the sixteen categories (improvements in domestic appliances). The weighted average cost of conserved electricity is 0.006 ECU/kWh.

3.2.3 Low/high cost range under effective policy regime

Much of the difference between our high and low CCE estimates results from policy feedbacks. For scenarios in which well-designed, effective energy efficiency policies are being pursued, the plausible uncertainty range for DSE costs narrows to that portion of our low/high span that is not influenced by the policy environment but reflects inherent data uncertainties.

We therefore construct a „policy high“ case that specifically applies to this context. In this case, policies again reduce mark-ups and prices of technologies below market trends. However, we retain unfavorable assumptions regarding operating hours and compensation for lost internal heat gains. Program administration costs decline only half as much. T&D credits are at the low end, corrected only for the effect of geographic targeting. On a weighted average basis across all sectors and end-uses, this high estimate is 0.023 ECU/kWh, compared to our low estimate of 0.006 ECU/kWh. The highest-cost increment is now 0.038 ECU/kWh, compared to 0.023 ECU/kWh for our low estimate.

3.3 Conclusion: previous studies overestimated costs

Given its comprehensive analytical framework, the inclusion of policy feedbacks, and a plausible extrapolation of demonstrated field experience, our work suggests that most cost assessments to date report unrealistically high efficiency costs that are not consistent with a policy context of serious implementation efforts. This is especially true when examining strong government policies to reduce carbon emissions and increase energy efficiency.

In round numbers, strong policies can be expected to yield weighted average costs of conserved electricity in the neighborhood of 0.01-0.04 ECU/kWh, compared to a conventional wisdom range that is about twice as high. These higher conventional wisdom estimates, which bracket our high estimate, reflect backward-looking assumptions that are at best suitable for private, short-term investment decisions. They are misleading when used for national policy assessments, in that they overlook basic patterns of economics and severely understate the potential benefits of energy efficiency-oriented policy action.

4. Cost effectiveness

4.1 Integration with supply sources

4.1.1 The future cost of electricity from new plants

The marginal costs of electricity from new plants are taken from several companion studies, (Parts 3A, 3C, 3D, and 3E) where we developed a low/high cost range for future fossil, nuclear, and renewable generating technologies and fuel prices. In the low case, coal, oil and gas prices for the utility sector remain largely flat at 1987 levels over the period till 2020. In the high case, oil and gas prices roughly double while coal prices increase by 50 percent over the same period.

Based on these data, and assuming a least-cost mix of generating sources (see Part 3A), our levelized marginal cost of *delivered* electricity (including distribution costs) for the 1990-2020 period range from about 0.041 ECU/kWh in the case of Low Fuel prices and Low Capital costs for new generating technologies (LF, LC) to about 0.053 ECU/kWh in the case of High Fuel prices and High Capital costs (HF, HC).[2]

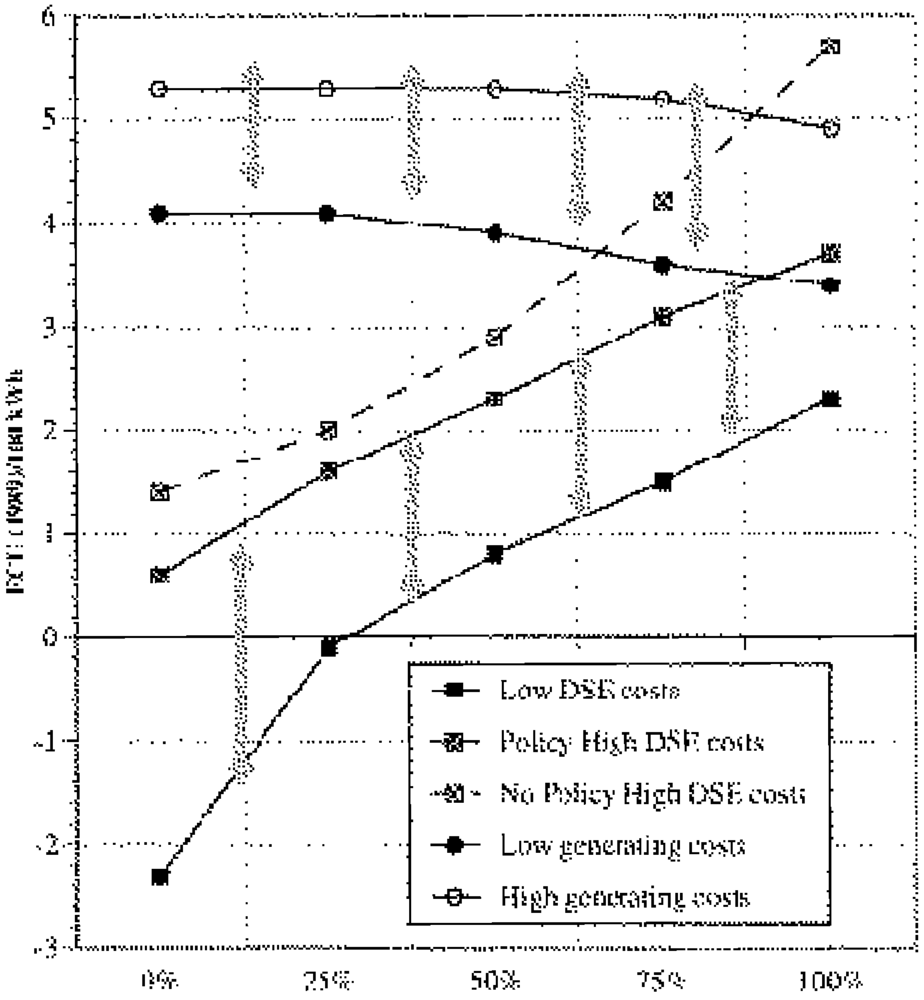


Figure 4-2: Cost Effectiveness of Western Europe's Demand-Side Efficiency (DSE) Resources Against Levelized Costs of Marginal Electricity Supplies (EU-5 region, 1995-2020)

4.2 Results: Cost-effective fraction of DSE resources

Based on Figure 4-2, the cost-effectiveness of year 2020 demand-side efficiency resources can be summarized as follows:

a) *Active climate policy or least-cost energy policy*

In this case, the feedback effects of aggressive policies reduce the costs of conserved electricity sufficiently to make virtually the entire demand-side efficiency resource cost-effective against marginal supplies even as the cost of marginal supplies declines:

- With the low/high cost range that would apply in an active policy context, more than 90 percent of Western Europe's electrical demand-side efficiency resource is robustly cost-effective (i.e., cost-effective against the entire low/high range of supply costs).
- On average, the electricity saved by implementation of all technical measures is 50-80 percent cheaper than the average kWh of additional electricity from new power plants.

b) *Worst case scenario (ineffective demand-side efficiency policies)*

- When high efficiency costs compete with low electricity costs, about two thirds of Western Europe's DSE resource is economically cost-effective.
- On average, savings from cost-effective measures cost 0.025 ECU/kWh. They are about 40 percent cheaper than the average kWh from additional electricity from new power plants.

4.2.1 Short-run versus long-run marginal costs

Would it be economically advantageous to postpone large-scale demand-side management programs until growth in demand has diminished currently existing excess capacity? A simple inspection of Western Europe’s supply curve of electrical efficiency resources suggests not. The short-run marginal costs of power generation from existing excess capacity typically fall in the range of 0.02-0.03 ECU/kWh (delivered costs at the point of end-use). Depending on which of our cost estimates is used, a minimum of 25-90 percent of Western Europe’s demand-side electricity resources are cost-effective against these short-run marginal costs.

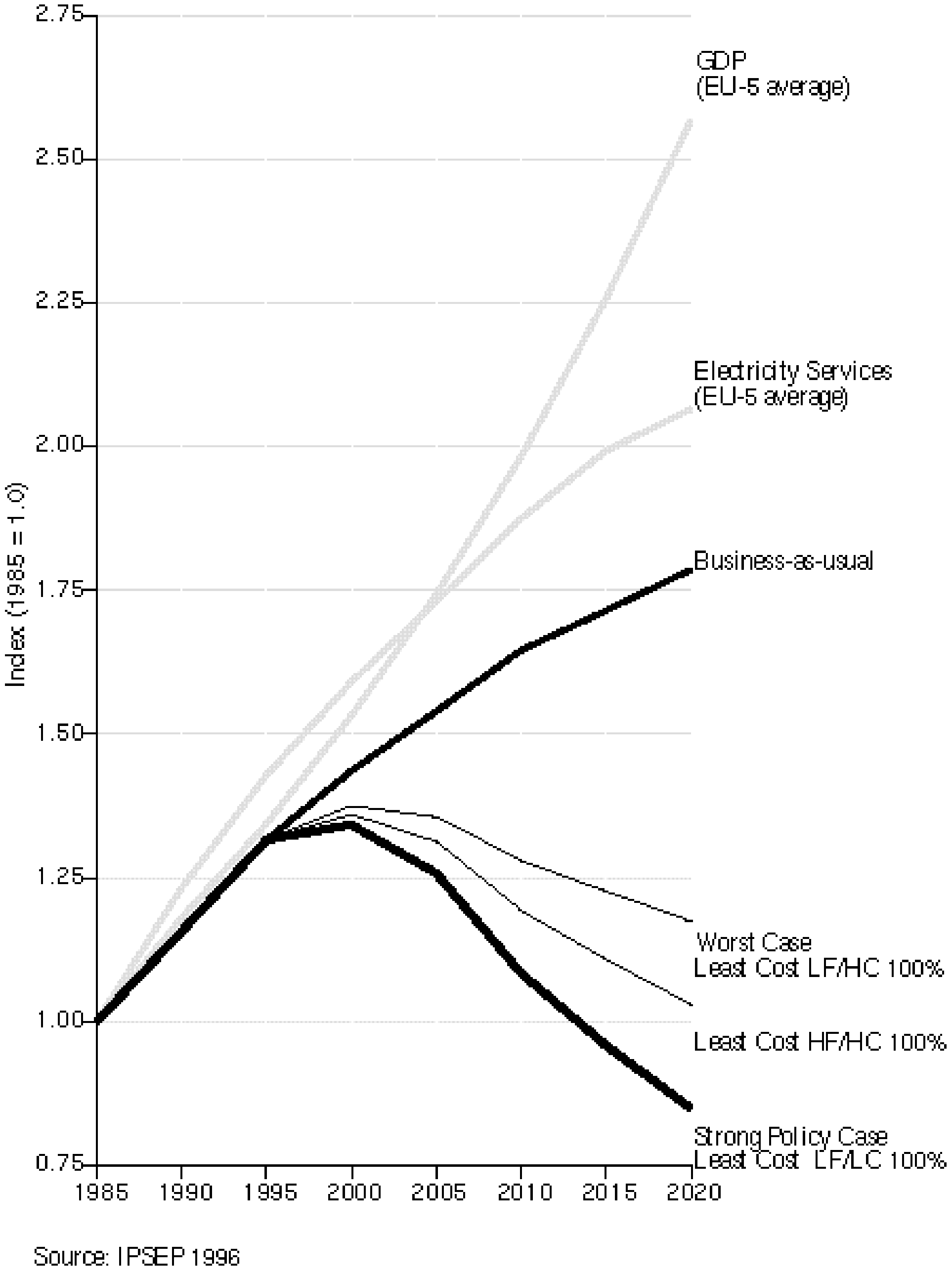
More importantly, demand-side efficiency resources have to be evaluated against the levelized cost of power generation during their useful life. Over a 20-year period, excess capacity will be gradually absorbed through growth and through the replacement cycle of generating stock. Though advanced gas turbine technology combined with currently low gas prices can result in generating costs from new plants that approach the upper end of the marginal cost range of existing plants, gas prices are projected to rise somewhat (low case) to significantly (high case) over the next 20 years. Because of this and because of the need for resource diversity, marginal generating costs averaged across all plants in service may rise somewhat to significantly over time to a higher long-run level based on new plants. If the net present value of future savings at higher electricity prices is not taken into account, delaying implementation policies may create lost opportunities in achieving cost-effective efficiency levels, notably in longer-lived electricity-using capital goods. As a result, the fraction of demand-side efficiency investments that is economically justified each year beginning now is larger than indicated by short-term generating costs.

4.3 How much money and carbon could Western Europe save?

These low-cost efficiency resources translate into major economic savings potentials over time:

- With aggressive and well-designed policy programs, Western Europe’s year 2020 bill for electricity services (including all investments in energy efficiency measures) could be reduced by 14-37 percent below the levels expected under business-as-usual policies.
- In round numbers, the corresponding absolute savings in the EU-5 region would be 20-50 billion ECU per year by 2020 (net of all investment costs). This range is equivalent to 0.3 to 0.7 percent of projected gdp in that year. If non-climatic externalities are added, the savings rise to at least 25-60 billion ECU per year.
- The net present value benefit of fully implementing the electrical efficiency resource in the 1995-2020 period is about 140-260 billion ECU for the EU-5 countries. Including externalities, cumulative savings are at least 150-300 billion ECU.

Using our implementation fractions, Figure 4-3 shows the range of year 2020 levels of electricity demand in the EC-5 region, and the associated range of cost-effective electricity savings.



Source: IPSEP 1996

Figure 4-3: GDP, electricity services, and least-cost levels of electricity demand in the EU-5 region

5. Conclusions

The analysis in this report has identified a major economic prize that is available to Western European governments, consumers, and firms. With aggressive policy reforms that promote effective competition between investments in more supplies and investments in more efficient electricity use, total year 2020 electricity service costs could be lowered by as much as 20-50 billion ECU per year before considering environmental externalities. These economic savings would be accompanied by equally significant environmental benefits. With welfare-maximizing policies aimed at fully implementing the cost-effective demand-side efficiency resource in the EC-5 power sector, all growth in electricity demand could be eliminated after the turn of the century. Demand in 2020 would drop somewhat below 1985 levels. Carbon emissions in the EC-5 power sector would be cut by 10-59 percent below 1985 levels while saving money.

The economic benefits of aggressive demand-side efficiency programs are found to be at least twice as large, and plausibly four times greater than the benefits that can be expected from reforming electricity supply markets alone. If the two reforms were combined, benefits would be two to five times larger. These relationships imply that current narrowly conceived liberalisation proposals entail major opportunity costs for consumers, firms, and society — costs that become even larger when environmental externalities are taken into account.

These opportunity costs call for an integrated market transformation approach (IMT) that links the competitive restructuring on the supply side with policies for creating effective markets for energy efficiency on the demand side. The directive on integrated resource planning (IRP) of the European Commission points in the same direction. Western Europe's governments would commit a serious economic and environmental blunder should they fail to broaden their concepts of utility sector reforms.

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— Part 3A. Low Carbon Electricity Futures for Western Europe
— Part 3B. Negawatt Power
— Part 3C. Fossil Generation
— Part 3D. Renewable Power
— Part 3E. Nuclear Power

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Endnotes

[1] Negative cost means that an immediate economic saving arises upon choosing the energy-efficient package over standard equipment now dominating the market. However, in the absence of policy reforms, high information costs and other transaction costs often inhibit such investments.

[2] These levelized marginal cost figures (five percent real discount rate) represent a least-cost mix of baseload, intermediate, and peaking plants for the year 2020 (see Part 3A of the IPSEP study).