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Methodological Comments on the Report of the Commission AMPERE

Prepared on behalf of Greenpeace Belgium

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Executive Summary

In October 2000, the Commission for the Analysis of the Means of Electricity Production and the Restructuring of the Energy Sector (AMPERE) provided its final report to the State Secretary for Energy and Long-Term Development of the Belgian Federal Ministry of Economic Affairs. Greenpeace Belgium has commissioned to the Wuppertal Institute a short study with the aim of a first scientific assessment of the AMPERE Commission report. The methodological problems of that report were considered the most important issue to focus on. This is, therefore, **a first short study that focuses on the methodology** used in the work and the report of the AMPERE Commission to derive their results, and to develop recommendations from these results.

The Wuppertal Institute's conclusion from the analysis of the **methods** used by the AMPERE Commission to analyse the demand of electricity and the potentials and costs of different electricity generation options is: **Because of severe methodological problems, it is not possible to justify the recommendations for the future electricity generation options given by the AMPERE Commission based on the Commission's own results**. The reason is that both the methods used to derive these results, and the insufficiency of the results themselves, do not allow the recommendations to be justified.

Most notably, the AMPERE Commission has not developed an integrated, bottom-up scenario analysis of electricity demand and supply. Instead, the Commission took the forecasts of aggregated electricity demand more or less as given, analysed the potentials and costs of individual electricity generation options, and compared these to the demand forecast, without any system integration of demand-side energy efficiency and different supply-side options, and without a stringent analysis of policies to realise the different potentials. The effects of the integration of the European electricity systems were also neglected. The **Commission was therefore not able** to estimate the total needed investment and costs for the future Belgian electricity supply system, including demand-side energy efficiency, in the internal European electricity market, nor the resulting total emissions.

Furthermore, also many of the results of the AMPERE Commission on **potentials and costs** of individual electricity supply options seem to be insufficient. For instance, the electricity generation potentials of cogeneration and many renewable electricity generation options appear by far underestimated, while the costs particularly of some cogeneration options (e.g., gas-fired combined-cycle cogeneration plants) appear overestimated. It was not possible, however, to analyse this in the necessary detail, since the AMPERE Commission does not provide enough detail to follow the methods how the potentials have been determined.

In order to generate a reliable basis for informed decisions on the future energy policy in Belgium, **we therefore recommend the development of a policy oriented** (goal: identification of necessary policy measures) **and discourse oriented** (goal: discussion of scenario results with all relevant groups) **integrated demand and supply side bottom-up scenario analysis for Belgium**. An integrated bottom-up analysis of both electricity demand and supply will be necessary to first assess the baseline development in the "business-as-usual" case. Only with such an analysis will it, second, be possible to analyse the differences between this baseline and alternative futures that might "match the societal, economic and environmental requirements of the twenty-first century" (as it was stated in the objectives of the AMPERE Commission). In **Chapter 6**, we present proposals for the **methods to be used in such an integrated bottom-up analysis**.

1 Introduction

In October 2000, the Commission for the Analysis of the Means of Electricity Production and the Restructuring of the Energy Sector (AMPERE) provided its final report to the State Secretary for Energy and Long-Term Development of the Belgian Federal Ministry of Economic Affairs. The objective of the AMPERE Commission's report is to draw up recommendations, based on the currently existing situation in Belgium, regarding future options with respect to the production of electricity in order that these will match the societal, economic and environmental requirements of the twenty-first century. The general economic and energy context as well as the evolution of electricity demand in Belgium have also been taken into account. The members of the AMPERE Commission have made their considerations for a period of 20 years and have dedicated their work to the technologies which could be placed in service and industrially used by the year 2020.

Following the publication of the report, Greenpeace Belgium has commissioned to the Wuppertal Institute a short study with the aim of a first scientific assessment of the report. The methodological problems of that report were considered the most important issue to focus on. This is, therefore, a first short study that focuses on the methodology used in the work and the report of the AMPERE Commission to derive the results, and to develop recommendations from the results. As far as it was possible with the limited time given, comments on some of the results presented in the reports of the AMPERE Commission were also developed.

The presentation of our comments is organised as follows: chapter 2 describes the general approach used by the AMPERE Commission to derive the results. Chapters 3 and 4 complement the general analysis with comments on the methods used to analyse the demand of electricity and demand-side management (chapter 3) and the options for electricity generation (chapter 4). In chapter 5, we draw conclusions on the appropriateness of the approaches used by the AMPERE Commission derive the results, and to develop recommendations from the results. Finally, in chapter 6 we present recommendations for a methodology, which is able to develop results that will allow policymakers an informed decision on a sustainable energy policy for the next two decades.

2 General Approach Used by the AMPERE Commission, and Questions Arising on this Approach

The general approach taken by the Commission AMPERE to derive the results can be described as follows:

1. In the first step, existing projections of the future demand of electricity in Belgium were collected and compared, and a sensitivity analysis was made as to the effect of different developments of the electricity demand on the CO_2 emissions until 2012. None of the referenced studies on the future electricity demand in Belgium seems to be based on a sectorial and end-use technology bottom-up analysis, and no further breakdown of the present electricity demand than in six main sectors is provided.
   Notwithstanding this lack of detailed information, the AMPERE Commission recommends a strong role for demand-side management (DSM) to exploit the potentials of end-use energy efficiency. This is well justified, since any DSM resources that are cost-effective compared to the societal cost of the energy supply system should be used.

2. In the second step, the AMPERE Commission proceeds to analyse how the “average” of the existing projections of the future demand of electricity in Belgium might be met with the possible options for electricity generation. For each of the potential technologies, two main parameters are given:
   (1) the social cost of electricity generation (technical production cost + external cost, e.g., due to environmental damages caused) is calculated;
   (2) the “plausible” potential for electricity generation (in TWh/year and/or in MW) is somehow determined by the AMPERE Commission.
   This “plausible” potential seems to be at least partly based on a ranking of the different electricity generation options by the AMPERE Commission using the social cost of electricity generation as a criterion. The Commission defines three groups of technologies, based on their relative position with respect to technical production cost and external cost.

3. Finally, the AMPERE Commission develops recommendations on the choice of future generation technologies based on the results concerning electricity generation potential and cost. Since the “plausible” potentials given by the AMPERE Commission for the low CO_2 options, i.e. cogeneration of electricity and heat, and renewable energies combined are only equivalent to about 15 to 20 % of the expected future electricity demand, the Commission strongly recommends electricity-only gas-fired combined cycle plants; is divided over the new build of coal-fired electricity-only power plants; and recommends to keep the option for future nuclear power plant concepts open through continued public and private research.

Looking at this general approach of the AMPERE Commission, the following questions need to be analysed in the subsequent chapters:

- Is the method used by the AMPERE Commission for analysing the demand side, and the potentials for demand-side energy efficiency, state of the art and sufficient for the Commission's objectives?
- Is the method used by the AMPERE Commission for analysing the potentials and costs of the different electricity generation options state of the art and sufficient for the Commission's objectives?
- Is it possible to draw the AMPERE Commission's conclusions and recommendations from the results on the demand of electricity and by simply comparing the different electricity generation technologies in terms of potential and costs?

We will, however, not examine the methods and results of the AMPERE Commission concerning the potentials, risks, and costs of future nuclear reactor concepts[1]. The Belgian government has taken the decision to phase out the existing nuclear power stations after each of them has reached a 40 years service life, and to not build new reactors. In this report, we consider this as a fact and do not study other scenarios, like faster phase-out or slower phase-out.

The crucial question is therefore not whether Belgium has to choose between "cancer" (risks of nuclear reactors and nuclear waste) and "polio" (CO_2 and other emissions from fossil-fuelled power stations), but whether it is possible for Belgium to phase out nuclear energy **and** achieve the climate protection targets without additional costs or with reasonable extra costs. For our analysis, the related question is: is it possible to answer this crucial question based on the results of the AMPERE Commission? If this is not the case, which kind of analysis would allow an answer to this crucial question?

[1] Although we were astonished by the precise figures for the risks and costs, which the AMPERE Commission presents for new reactor concepts such as the AP600 or MHGTR power stations, which to date do not even exist as commercial prototypes.

3 Comments on the Approach Used for Demand-Side Energy Efficiency

3.1 Assessing the Future Development of the Electricity Demand

As already mentioned in Chapter 2, with respect to the future demand of electricity and to demand-side energy efficiency, the AMPERE Commission mainly collected and compared existing projections of the future demand of electricity in Belgium, and made a sensitivity analysis as to the effect of different developments of the electricity demand on the CO_2 emissions until 2012. None of the referenced studies on the future electricity demand in Belgium seems to be based on a sectoral and end-use technology bottom-up analysis, and no further breakdown of the present electricity demand than in six main sectors is provided.

The only further information that is presented is a comparison of the electricity intensity of GDP in several EU countries and the USA, from which it becomes obvious that the electricity intensity has increased in Belgium over the last 20 years by more than 10 %, while it has almost been stable in the neighbouring Netherlands, and even started to decline in countries such as Austria, Germany, or the UK. Since no bottom-up analysis of electricity demand in Belgium seems to exist, it is not possible to determine the reasons for these different developments.

Such a methodology certainly is not state of the art in the assessment of the future development of the electricity demand. State of the art is a **bottom-up scenario analysis** already for the “business-as-usual” scenario. This is the scenario, in which the past development in the autonomous increase of the energy efficiency of buildings and equipment is continued into the future, and the effect of already existing policy instruments is taken into account. In Chapter 6.1, the principles of a bottom-up scenario analysis are described. Such a bottom-up approach has been used, e.g., by the Prognos AG and others since the mid-1980ies in their periodic updates of the “business-as-usual” scenario made for the German Federal Ministry of Economy (cf., e.g., Prognos/EWI 1999 for the latest revision), and is the standard technique also in the scenario analyses of the Wuppertal Institute and other German institutes.

Such a bottom-up scenario already for the “business-as-usual” case is on one hand a plausible basis for combination with a bottom-up scenario for the generation of electricity. On the other hand, the underlying model immediately allows calculating the effects of increased demand-side energy efficiency through an appropriate mix of policies stimulating economic action, since increased demand-side energy efficiency just equals higher implementation rates for the technologies with improved energy efficiency in buildings and equipment. A bottom-up analysis would therefore have been **indispensable** to reach the objectives of the AMPERE Commission.

3.2 Assessing the Potentials for Demand-Side Energy Efficiency

With respect to the potentials for increased demand-side energy efficiency, the AMPERE Commission again only refers to existing other studies or analyses for Belgium. The main source given here – in the Synthesis report, but not in the Executive Summary and in the Conclusions and Recommendations! - is the national programme for the electrical energy production and transport resources for the period 1995 to 2005[2]. This plan has identified for this 10 year period (cf. Chapter C 7.2 of the AMPERE Commission's synthesis report)

1. a technical potential of 40 %;
2. an economic potential of 18 %
3. and a "realistic" potential of 8%, i.e. the potential that can actually be achieved through demand-side management programmes and services of the energy companies.

Furthermore, the AMPERE Commission's synthesis report cites an estimate of 30 % economic potential between 1995 and 2010 from STEM (1995).

It is not possible to assess the quality of the methods used by the national programme for the electrical energy production and transport resources for the period 1995 to 2005 to achieve these figures, as these methods are not described in the report of the AMPERE Commission. However, for a 10 year period, they are similar to results of bottom-up analyses of the technical and economic potentials achievable in a 10 year period, and of the potential achievable through demand-side management (DSM) programmes and services of the energy companies. E.g., the experiences with actual DSM programmes in Denmark and other EU Member States cited in Wuppertal Institute et al. (2000) as well as several European Integrated Resource Planning studies during the 1990ies - e.g., by the Danish utilities (ELSAM 1994); the Dutch utilities (SEP/Ijsselmij 1994); Stadtwerke Hannover, Germany (1995) - showed: ca. 4 to 8 % of the forecast electricity consumption can be saved in a timespan of 7 to 10 years through cost-effective DSM.

However, in a timeframe longer than 10 years, both the technical and economic potentials, as well as the fraction of the potentials that can be achieved through DSM can be higher. The achievable potential can also be increased already in the first 10 years by using other energy efficiency instruments along with DSM. The question is therefore, which energy efficiency instruments should be used directly by energy national policy, and which policy framework can be created to stimulate DSM by energy companies and others. This question is dealt with in the next section 3.3.

[2] The national equipment plan is drafted by the electricity sector BCEO, which unites both producers (Electrabel/SPE) and the distribution sector (which is 80% mixed with Electrabel/municipalities and 20% „pure" intermunicipalities or distribution companies). Formally, it is then submitted to the government (in 1995 for the last time), which can make some comments. So in fact, this conservative but probably not grossly underestimated assessment of the potential of DSM is coming from the electricity sector itself.

This conclusion for this section 3.2 is, however, that again the methods used by the AMPERE Commission are not state of the art and are insufficient to reach the Commission's objectives. In order to reach the AMPERE Commission's objectives, a **bottom-up analysis of** the current and future **demand** for electricity, and of the technical and economic **potentials** for electric end-use energy efficiency that exist in time frames of 10, 20 or more years **is needed** as a basis for discussing **policy packages** that address these potentials, and the fraction of the potentials that the policies can help to realise. The methods for developing such an analysis are described in see Chapter 6.1. The only bottom-up study, at least of economic potentials, that we know of for Belgium is the report by STEM (1995) that the AMPERE Commission also cites, but does not seem to use in their further work.

3.3 Instruments for Stimulating Demand-Side Energy Efficiency

Chapter C of the AMPERE Commission's Synthesis report discusses a variety of instruments that can be used by government, electricity companies (most notably the intermunicipal companies) and others to help energy end users in all sectors to increase the energy efficiency of buildings and equipment beyond "business-as-usual" activities.

Very important is the hint given in Chapter C of the Synthesis report that also in a liberalised electricity market, policy can create a framework that is compatible with the competition in wholesale and retail supply, but allows energy companies to engage in demand-side management activities to increase end use energy efficiency. Particularly, the proposal of an independent energy efficiency funds refinanced from a non-bypassable levy on all kWh consumed is presented in Chapter C of the AMPERE Commission's Synthesis report. This could be the main policy mechanism for providing a competition-compatible funding for energy efficiency programmes by electricity companies and other actors, as also proposed for Belgium in the report of the SAVE study on least-cost energy services (Wuppertal Institute et al. 2000).

However, there is a discrepancy between Chapter C of the Synthesis report and the Conclusions and Recommendations/Executive Summary in the scope of instruments and mechanisms presented. In the Conclusions and Recommendations/Executive Summary, no mention is made of the levy and funds proposal for securing DSM in the liberalised electricity market, and the list of DSM activities given is restricted to mainly information, commercial energy services, and tariff structure activities. While these are important, they will not be sufficient to address the full potential of end-use energy efficiency (Wuppertal Institute et al. 2000).

It can therefore be concluded that in Chapter C of the Synthesis report, the AMPERE Commission has presented instruments that would allow to achieve its objectives, while those instruments given in the Conclusions and Recommendations would not fully allow this.

4 Comments on the Methods Used for Assessing the Potentials and Costs of Supply-Side Resources

4.1 General Assumptions: Fuel Prices and Other Important Parameters

Concerning the fuel prices, estimates for the development of oil prices are crucial. The AMPERE Commission assumes a distinct increase of the oil price from 18 $/barrel in 1999, over 24.3 $/barrel in 2010, and 31 $/barrel in 2020, to 37.2 $/barrel in 2030. Compared to 1999, this leads to an increase of 107 % until 2030[3]. Taking the relatively high prices in 2000 into consideration (approximately 26 $/barrel) the increase declines to 43 %. In contrast to these assumptions, in the most recent “Energiereport” for the German Ministry of Economy describing a Business-as-Usual future path, the Prognos Institute expects a nearly constant price level for oil until 2010 (compared to 1999 but of course with a high volatility), and only moderately increasing prices until 2020 (Prognos/EWI 1999). However, it should be noted that the share of oil imports from the OPEC region is expected to increase in Germany, probably leading to higher uncertainties.

Prognos as well as the AMPERE Commission assumes a continued interconnection between the oil and gas prices, which for Prognos results in an increase of gas prices from 0.65 EURc/kWh (0.26 BEF/kWh) (import price at border) in 1998 over 0.71 EURc/kWh (0.28 BEF/kWh) in 2010 to 0.95 EURc/kWh (0.39 BEF/kWh) in 2020. In contrast to this, the AMPERE Commission assumes nearly a doubling of gas prices between 2000 and 2020, leading to much higher prices than Prognos (1999) expects.

For coal prices, the AMPERE Commission and Prognos come to the same expectations of almost constant prices in the future. Therefore, also under German framework conditions the cost competitiveness of coal power plants will improve with relation to oil and gas fired power plants. But not as much as assumed by the AMPERE Commission.

Concerning the current consensus about the nuclear phase out from June 2000, estimates about prices for new nuclear power stations are not relevant in the German discussion, but recent cost analyses for the existing plants are available. They show that many of the older power plants will become uneconomic if bigger investments for retrofit measures (especially for safety applications) become necessary. Based on empirical experience that is the time after more than 25 years or 30 years of operation.

Besides the fuel prices, the real discount rate is one important general assumption for the determination of electricity costs. The settings of the AMPERE Commission are comparable with other assumptions concerning examinations of the national economy. But it is remarkable that cost analysis based on real discount rates does not deliver suitable

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[3] all prices in $\$_{1999}$

results from the customers' (e. g. industrial companies as well as private persons) point of view. In practice, investors calculate with higher discount rates, e.g., to take risk aspects into consideration. As opposed to calculations for the national economy, private customers have to bear in mind additional costs like taxes etc. Especially in the transport sector, but also concerning electricity consumption, fuel taxes are important and influence the total costs.

Regarding external costs, the AMPERE Commission mainly refers to the results of the European ExternE study. This is not the place to present a thorough critical analysis of the methods and results of the ExternE study. Just a few critical remarks on the methodology have to be made, however.

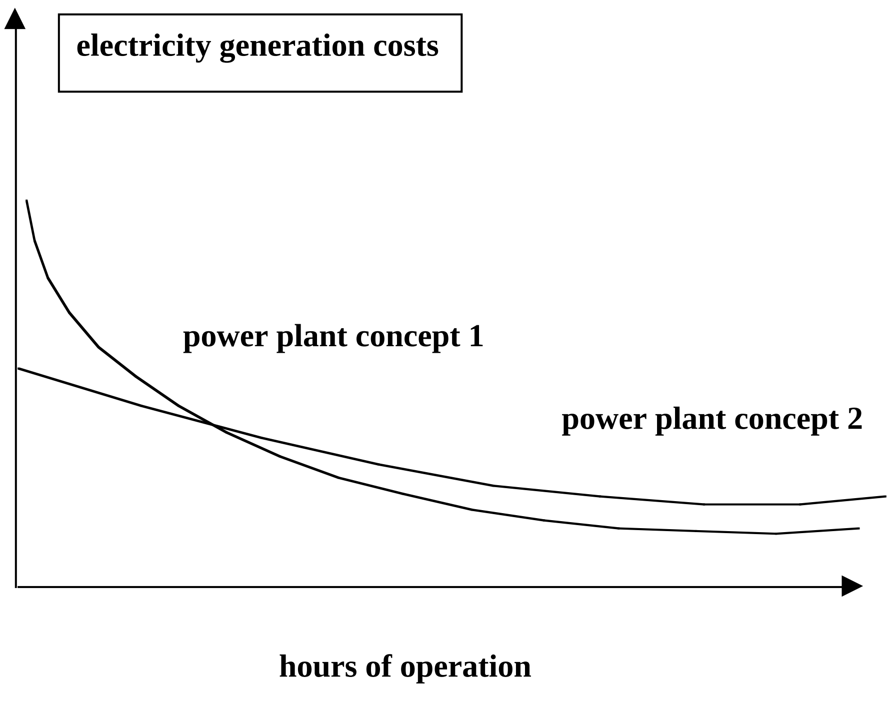
- The AMPERE study uses a "damage cost" of 741 BEF/ton CO_2. The calculation of damage costs for CO_2 poses such large methodological differences that many authors (e.g., Hohmeyer 1995) refrain from this exercise, and recommend instead of "external costs" to use physical constraints, e.g., for the absolute amount of emissions (in Mt CO_2 per year and country), that reduce over time, similar to the Kyoto targets. The biggest problem with the calculation of a "damage cost" for CO_2 is the long timescale involved. Since the damages can occur in 100 or 200 years from now, the discount rate used to calculate the "damage cost" is crucial, and the choice of this discount rate can in fact lead to negligible or tremendous (e.g., 0.40 EUR/kWh) "damage costs" (Hohmeyer 1995)
- Furthermore, it is highly questionable to use relatively high "damage costs", when the costs of avoiding a ton of CO_2 are much lower, or even negative (e.g., Thomas 1995).
- Finally, the figures given by the AMPERE Commission for the risk and external costs of nuclear reactors are closer to the lower end of the figures that were published for Germany (equivalent to between 0.012 and 0.89 BEF/kWh, cf. Wuppertal Institute 1999 for a discussion). More importantly, however, the range of the absolute value of the damage of one single severe nuclear accident is extremely high: between 0.5 and 5 billion EUR (ca. 20 to 200 billion BEF). This is a totally different quality of a damage event from any other energy source, rendering the concept of risk (probability times damage) less useful for assessing the acceptability of nuclear energy.

It is therefore recommended to carry out a thorough and critical analysis of the methods and results of the ExternE study, instead of just accepting these results.

4.2 Cost calculation approach

The cost calculation approach of the AMPERE Commission for electricity generation costs is based on a static comparison, a typical methodology for quick cost analysis using the main cost components (fuel costs, capital costs, other variable costs). For assessing the competitiveness of cogeneration power plants, a typical cost calculation approach has been carried out. The AMPERE Commission as well compared the total cost of the cogeneration plant with the costs of electricity generation and heat production in separate units. In other words, for the determination of the resulting electricity costs in cogeneration plants, they take a bonus for the heat production in separate heat supplying plants into account.

Unconventional, however, is the use of maximum expected hours of operation as a basis for the cost calculation. Within this approach, only the planned and unplanned unavailability is taken into account, but this does not say anything about the suitability of the power plant concepts in the different load areas. Normally, power plants with lower capital cost are used in peak and intermediate load, while those plants with higher capital costs but relatively low fuel costs are dispatched in the base load area. Taking only the maximum hours of operation into consideration, always the same power plants show the minimum electricity generation costs. Especially power plants with high capital costs (like nuclear power plants) will be unduly favoured. In practice, one has to recognise the different characteristics of operation and has to decide about the optimal mix of power plants for the whole power plant system, including the provision of peak, intermediate, and base loads.



Especially for the electricity generation based on renewable energies, this calculation methodology is not appropriate. Because of meteorological characteristics, wind energy converters as well as photovoltaic modules cannot contribute by 100 % to the guaranteed power. But due to compensation effects between wind and/or PV plants in different locations, the contribution is much more than zero. That is not the most important point, more important is that electricity from renewable energies normally is able to substitute electricity generation by intermediate and peak load plants. The price of power generated in these units has to be compared with the resulting electricity costs from renewable energies. In complete systems calculations there is another effect, which has to be taken into account. The use of decentralised systems like renewable energies leads to the opportunity to decrease losses in the distribution and transportation of electricity, thereby avoiding the related costs.

The AMPERE Commission already outlined that especially for cogeneration plants the chosen methodology is a very simple one. Ideally, it would be necessary to take the different temperature levels of the heat demand of the customers into consideration to come to detailed case by case examinations of the cost situation. The cost calculation of the AMPERE Commission only distinguishes between low temperature heat for industry, residential and service sector, and high temperature heat for industry. More detailed estimates are not possible in such an overall study, but it might be useful to add some detailed case studies to the simple cost calculation. With this, the specific conditions for cost calculation of cogeneration plants would become more transparent.

Anyway it is not understandable why cogeneration plants in the service sector heat market are calculated on the basis of only 50 % of maximum number of operation hours (for industrial plants the limit used by the Commission is 80 %). Those plants often will be planned for the provision of the heat base load (providing the hot water demand and possibly also space cooling in summer). Especially decentralised cogeneration power plants are able to reach much more hours of operation. In short calculations often more than 5.000 hours per year are used.

4.3 Assessment of Potentials and Costs of Renewable Energy Sources

Before commenting the individual forms of renewable energy, we would like to give some remarks on methodological aspects of the AMPERE Commission's analysis that are very important for the assessment of the outlined potentials, costs and possibilities in general[4].

First of all, the methodology for the determination of the potential is not clear. It is not possible to follow up how the Commission arrived at the amount of the capacity that is recommended to install until 2020. In the report, one can find only a few remarks like „it should be possible...“ or „a realistic estimate...“, but the underlying scientific approaches are not described.

[4] All comments are based on the available reports in English; there might be more information in the detailed reports that could not be considered in the following analysis, and would allow to follow up the path to the AMPERE Commission's recommendations.

Second, the AMPERE Commission does not reveal the technical potentials of the various energy forms, nor the potentials achievable with certain policies, but only its personal expectations relating to the year 2020. Therefore, there is no objective and, probably, no science-based statement on the existing renewable energy potentials at all. This point is very critical because the Commission uses the outlined potentials (expectations) for showing some further aspects that were not in the primary focus of the Commissions work: „As you can see, ... large scale of production with renewable forms of energy is impossible, even in the longer term“ (pg. 88). Such far-reaching conclusions should definitely be based on detailed explorations and not on personal expectations.

Third, the Commission had a strong national focus on the Belgian energy system, although there is an on-going European process of integration. Belgium itself is a very densely populated country, and the climate conditions are not as good for use of renewable energies as in other European countries. The result is, that there must be fewer potentials relative to the population or GDP. But, one can find countries within Europe that have greater potentials of renewable energies than demand (e.g., Denmark is able to produce more than 10 times its electricity demand only by offshore wind-farms, the Netherlands almost twice its electricity demand; cf. Matthies et al. 1995). Within a globalised world, and especially within an open and liberalised European energy market, one should always take the whole relating market and options into account.

4.3.1 Wind energy

On one side, the underlying costs and load factors are similar to other studies, experiences and assumptions. The only difference between the AMPERE Commission's and other analyses is the estimate concerning offshore wind energy, because the AMPERE Commission speaks about today's costs but does not involve learning curve effects. On the other side, the comparisons between the conversion rates of gas-fired combined-cycle power plants and wind energy converters, as well as the explanations concerning the operation times of wind generators suggest that there are a lot of disadvantages while using wind energy. In order to avoid such comparisons, the International Energy Agency (IEA, Paris) introduced the „conversion rate method“ some years ago. This means that all renewable conversion technologies are calculated with the defined conversion rate of 100 %, because a conventional power supply technology is not to be directly compared with a renewable electricity generation technology[5].

Apart from that, there are important differences between the potentials sketched by the AMPERE Commission and the results of other European studies on potentials of wind energy in Belgium (see the following table).

[5] Comments on „operation time“, see ‚Conclusion‘.

Table 4-1: Wind energy potentials in Belgium in different studies (in TWh/a)

	AMPERE	Other studies*
Onshore	1.2 – 2.4	2.7 - 5
Offshore	3	24

*LTI 1998; Matthies et al. 1995; Eurosolar 1993

Caused by the lack of information about the AMPERE Commission's assumptions and methods, the potentials presented in the report of the AMPERE Commission could not be assessed. But the above mentioned differences advise to elaborate the potentials in more detail.

Furthermore, it has already been mentioned that the increasing integration of the European electricity system will make it possible to import electricity from renewable sources, particularly since a mutual recognition of green energy certificates between Belgium, the Netherlands, Germany and Denmark is currently under negotiation. This is particularly important for wind energy, given the **potentials for offshore wind energy** outlined in Matthies et al. (1995). For the five EU countries, Belgium, the Netherlands, Germany, Denmark, and the UK, the technical potential for offshore wind energy totals **1,933 TWh/year**, equivalent to **320 % of their annual electricity consumption**.

Table 4-2: Offshore wind energy potentials in five European countries

	Maximum offshore potential (TWh/a)	Annual electricity consumption (TWh/a)	Possible contribution to national consumption (%)
Belgium	24	63	38
The Netherlands	136	76	180
Germany	237	432	55
Denmark	550	32	1708
UK	986	321	307
Total	**1933**	**605**	**320**

Source: Matthies et al. 1995

4.3.2 Bioenergy

As the Commission already mentioned, the use of biomass is a very „broad concept with a broad range of supply sources, actors and technologies“. AMPERE outlined the following available sources:

- Energy crops and wood residues
- Water treatment sludge
- Agricultural residues

- Household and industrial waste
- Landfill gas

In spite of this list of options, the Commission describes only a very few options of using biomass. For instance, the wide possibilities of using industrial or commercial waste (untreated wood, fat etc.) do not seem to be taken into consideration. Also the very interesting option of co-fermentation (dung and liquid manure combined with high-fat waste) was not described. There is also a lack of information about modern gasification technologies, that probably could be the most interesting option in using biomass resources. Another very important future technology, the fermentation of „black water“ from households (vacuum toilet), is neither integrated. Experiences in Germany show that about 25 to 30 % of the households' energy demand could be covered with this technology.

Furthermore, one can find a few data that are not comprehensible, e.g. the net conversion rate of dung/liquid manure to electricity is approximately 20 to 25 % (AMPERE writes 5 %). However, the revealed costs of between 2 and 4 BEF/kWh are similar to other studies' estimates.

From the point of the Wuppertal Institute, the development potentials are difficult to comprehend and to assess. First of all, the methodology used by the AMPERE Commission is not described, it is once again only an expectation („a realistic estimation“, p. 85). On the other side, there are only a few informations about the technical potentials of bioenergy in Belgium. LTI (1995) showed a primary energy potential of 45 TWh/a, completely converted into electricity this would equal 14 to 18 TWh/a (compared with 0.92 to 3.5 TWh/a given by AMPERE). Another clue about the possible share of biomass in Belgium could be the following. We made a rough estimate with the household waste that showed 1.1 to 1.5 TWh_{el}/a only for this technology (without „black water“)[6]. Furthermore, the potentials of wood and agricultural residues as well as energy crops are normally much higher than those presented in the report by the AMPERE Commission.

4.3.3 Photovoltaic energy

In the case of the environmental impacts of photovoltaic (PV) cells, there is an inconsistency within the explanations concerning the photovoltaic technology. On the one hand the Commission estimates that PV cells will be competitive by the year 2020, on the other hand the electricity production rises only from 0,3 TWh/a in 2000 to 0,5 TWh/a in 2020. Compared with the technical potentials (9 to 37 TWh/a, Eurosolar 1993), that production level seems to be very low.

Another critical aspect is the outlined necessity of the „large-scale storage“ of electricity caused by the changes in light intensity. These changes are really a difficult aspect, but in

6 Specific amount of waste: 170 kg/cap*a; dry substance 35 %, gas factor 0,45 m^3/kg; energy content 23,5 MJ/m^3; conversion rate biomass to electricity 35 %

order to assess this technical problem, one has to make very detailed, short-time system analyses of demand an supply (see also ‚Conclusion‘).

4.3.4 Hydropower

The description of the options and potentials of hydropower is similar to those of other studies (Eurosolar 1993, LTI 1998).

4.3.5 Conclusion

Based on the outlined low potentials of renewable energy sources in Belgium, the AMPERE Commission concludes that, even in the longer term, the large-scale production of electricity from renewables „is impossible“. As we have seen before, the technical potentials are much higher or seem to be much higher than expected by the Commission. One further evidence for this serious underestimation of the potentials for renewable energies are the results of the ODE study (1997). This study showed technical potentials of electricity production from renewable energy sources of ca. 9 TWh/year realisable by 2020 for Flanders alone, of which 1.2 TWh/a from onshore wind, 4.5 TWh/a from offshore wind, 3.7 TWh/a from Biomass, 0.1 TWh/a from hydropower, and 0.5 TWh/a from PV[7].

Apart from that, system effects between the different forms of renewable energies are totally not taken into account by the AMPERE Commission. For example, compensating effects between wind and photovoltaic energy may lead to higher shares as one can estimate based on a single technology view (as has been analysed for Germany, intermittent power generating systems could rise up to a share of 15 or 20 % without the necessity of large-scale storing techniques or back-up/reserve systems). The state of the art scientific method for assessing renewable options is to develop detailed, short time interval analyses of the electricity system, based on long term experiences concerning both the climate conditions and the demand structure (load curves). We could not find any systemic approach similar to this in the renewable energy chapter of the AMPERE Commission, so that the methodological basis seems to be very weak.

Furthermore, in order to estimate the possibilities of renewable energies one has to involve at least the neighbouring countries, or better the whole European system. E.g., the offshore wind energy potentials for Belgium alone derived by Matthies et al. (1995) are 24 TWh/a, i.e. ca. 30 % of the Belgian electricity consumption. However, taken only Belgium and the Netherlands together, the potential given in Matthies et al. (1995) is 160 TWh/a, which is slightly more than the combined electricity consumption of both countries. Without looking at the European internal electricity market, realistic conclusions are thus not possible.

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[7] Furthermore, passive cooling in new buildings and daylighting in non-domestic buildings can save another 5.5 TWh/year. The study involved all relevant scientists and academics involved in this area of research in Belgium.

4.4 Cogeneration

4.4.1 Power generation Potential and contribution to CO_2 reduction (ref. page 68ff)

Normally, one speaks of a “good” cogeneration system if a fuel saving or a reduction of the CO_2 emissions can be realised. The AMPERE Commission defined a quality index (QI) for describing the fuel savings. The most important aspect concerning the determination of the QI is the definition of the reference case describing the separate production of electricity and heat. In this context we have to distinguish between the comparison to the current situation (case I) and the question, which power plant should be built in the case of a growing demand or as substitute for old and inefficient existing plants (case II). In case I it is necessary to compare the energy consumption of the cogeneration system (including additional heating systems for the peak load) delivering electricity and heat with the current power plant mix and an average heating system (normally a mixture of gas and oil fired installations, additionally the differences between process heat and space heating have to take into consideration) satisfying the same customer demand of heat and electricity. For Belgium, with its high amount of nuclear power and a resulting specific CO_2 emission factor below 0.3kg CO_2/kWh_{el}, only a few cogeneration systems are able to realise a CO_2 reduction. Therefore, without any given necessities for modifications of the power plant system, the usefulness of the installation of a new cogeneration power plant will have to be discussed case by case.

Otherwise, if there is a growing demand for electricity, a necessity to substitute older plants by new ones or a demand for action concerning political decisions (e. g. the nuclear phase out decision in Belgium and Germany) a different reference case will have to be chosen. In doing this, it is necessary to separate between the decision about the selection of the fuel and the decision if or if not a cogeneration plant shall be installed. In other words: a coal fired cogeneration system must be compared to a coal fired power plant for separate generation of electricity and an average heating system (consisting of gas and oil fired installations). Likewise a gas fired cogeneration system must be compared to a gas fired power plant (e. g. gas-fired combined-cycle (CC) power plant) and an average heating system. This is especially true for a country like Belgium where currently more coal fired power plants exist then gas fired ones, and where also the installation of new coal power plant in future is not unlikely. Therefore, we think the outlined specific potential of cogeneration systems to contribute to a CO_2 reduction was underestimated by the AMPERE Commission using only gas-fired CC plants as the reference case for the separate electricity generation.

In Germany, the new climate protection programme of the government intends a doubling of cogeneration electricity generation until the year 2010. Starting from now approximately 70 TWh_{el}, the expected additional CO_2 reduction potential of the doubling target is calculated as 23 Mio. t CO_2. This corresponds to ca. 2,8 % of the total CO_2 emissions of Germany, and more than 8 % of the CO_2 output in the electricity sector.

Including the current cogeneration plants, the total contribution of combined heat and power generation to CO_2 reduction will be more than 45 Mio. t CO_2.

Furthermore, in the report of the AMPERE Commission we do not understand the statement that a use of cogeneration systems following the discontinuous operation mode or with low annual hours of use leads to an increase of operation of coal power stations. It is obvious that cogeneration plants, already for economic reasons, have to be constructed and planned for a continuous operation of more than 5,000 or 6,000 hours per year. Therefore, the operation mode of those power plants is comparable to intermediate load and sometimes even to base load power plants. Furthermore, the probability for shutdowns/breakdowns of the units is usually not higher than for other power stations. In case of unexpected stops, normally gas fired power plants are used to provide the electricity demand of the customers. Of course it may be that in Belgium this is the task of coal fired power plants. In any case the same units are necessary for substituting cogeneration plants in case of shut downs as well as nuclear power plants. Therefore, both types of electricity generation system will receive a CO_2 malus if they are not contributing to the provision of the given demand as necessary.

In opposite to economic disadvantages outlined by the AMPERE Commission, we have to point out that cogeneration plants have several economical advantages. Often they are characterised by a relatively low installation capacity (per unit). That means that for the same power demand more units are necessary. According to this and following probability calculations ($\sqrt{1/n}$ criteria) less reserve capacity – both in generation and in transmission and distribution - is necessary to ensure that the electricity demand can be met.

The AMPERE Commission estimates the potential for installing cogeneration units in Belgium on the order of magnitude of 1 GW_{el}. Following the discussion above (reference case for the determination of QI), economic features, the current share of electricity generation by cogeneration plants, and the experience from other countries this seems to be very low. Table 4-3 shows that the current contribution of cogeneration in Belgium is relatively low compared to the situation in other EU countries. No dramatic changes will occur if the additional potential outlined from the AMPERE Commission will be realised. But already based on the currently existing plans (e. g. the 800 MW_{el} cogeneration plant for BASF in Antwerpen by RWE and Electrabel), it can be expected that the potential estimated by the AMPERE Commission will be topped.

Table 4-3: CHP shares of total electricity generation, and average electricity prices (incl. taxes)

	CHP share electricity generation 1996		electricity price (Euro/100 kWh) and relation to Germany 1997)	
		located in the public electricity sector	private customers (3300 kWh/a)	industry (50 GWh/a)
Belgium	5%	37%	11,9 / 97%	5,1 / 77%
Denmark	**50%**	**95%**	**6,3 / 51%**	**4,1 / 62%**
Germany	12%	50%	12,3 / 100%	6,6 / 100%
Finland	**34%**	**58%**	**7,2 / 59%**	**3,3 / 50%**
France	1%	33%	9,6 / 78%	4,7 / 71%
Greece	3%	13%	6,1 / 50%	4,5 / 68%
Great-Britain	6%	0%	9,9 / 80%	5,9 / 89%
Ireland	3%	0%	8,5 / 69%	5,7 / 86%
Italy	13%	0%	16,5 / 134%	5,5 / 83%
Luxembourg	**31%**	**0%**	**10,5 / 85%**	**5,0 / 75%**
Netherlands	**35%**	**0%**	**9,1 / 74%**	**5,2 / 79%**
Austria	**29%**	**70%**	**9,7 / 79%**	**6,4 / 97%**
Portugal	13%	0%	12,4 / 101%	5,4 / 83%
Sweden	8%	76%	6,7 / 54%	3,5 / 53%
Spain	7%	0%	9,7 / 79%	6,4 / 97%

Source: Euroheat&Power 1998

Concerning the cogeneration contribution to the electricity system there is an other interesting fact outlined in table 4-3. **In most countries with a high amount of cogeneration, the average price for electricity is relatively low**. This, along with the estimates from other institutions leads to the expectation that the additional potential for cogeneration systems in Belgium is much higher than determined by the AMPERE Commission. Cogen Europe, for example, expected an additional cogeneration potential from 1500 to 3000 MW already until the year 2005 (Cogen Europe 1997), especially in the frame of public-private partnerships between the two main utilities in Belgium and industrial companies.

4.4.2 Electricity generation costs (ref. page I42ff)

In chapter 4.2 we outlined some questions and problems concerning the cost calculation for cogeneration by the AMPERE Commission. This is not at all the case for the chosen methodology (bonus methodology[8]) but for the assumed utilisation rate which can be higher than 50 % for cogeneration plants supplying heat for the residential and service sector as well. Taking the usual problems with those typicised examinations into consideration, it is possible to compare the resulting costs for electricity between cogeneration systems and power stations with a separate electricity supply. When applying this, some results of the AMPERE Commission are not transparent and understandable. While the costs for electricity supply from gas turbines in cogeneration units are lower than for gas turbines used only for electricity generation, the same comparison for gas-fired CC power plants by the AMPERE Commission yields lower costs for the non-cogeneration CC plant. Maybe this is caused by the doubtful assumptions for the utilisation rates of the cogeneration CC unit. In our opinion these results must be wrong (cf. table 4-4 which shows a cost comparison under the German frame conditions). Furthermore, a description of coal fired cogeneration plants is missing.

Table 4-4: Electricity generation costs for gas-fired combined-cycle power plants (cogeneration and electricity only) using an economic (company) point of view

	Cogeneration		**Electricity only**
electrical capacity (MW_{el})	**20**	**100**	**500**
thermal capacity (MW_{th})	20.93	91.3	-
electrical efficiency (-)	0.43	0.46	0.57
thermal efficiency (-)	0.45	0.42	-
total efficiency (-)	0.88	0.88	0.57
specific capital costs (DM/kW_{el})	**1200**	**1000**	**900**
full load hours (h/a)	5.000	5.000	5.000
discount rate (%)	8.9	8.9	8.9
years of depreciation	10	12	15
fuel price (DM/MWh)	22	22	22
Annual cost calculation (DM/kW*year)			
capital costs	186.2	138.9	111.0
cost for maintenance, taxes, insurence	72.2	59.0	13.5
costs for labour	12.0	9	9.6
fuel costs	255.8	239.1	193.0
other costs	7.2	5.4	7.0
total costs	533.2	451.4	324.1
profit for heat sale	208.1	181.6	-
total cost electricity generation	325.0	269.8	324.1
resulting electricity costs ($EURc/kWh_{el}$)	**3.32**	**2.76**	**3.32**
resulting electricity costs (BEF/kWh_{el})	**1.34**	**1.11**	**1.34**

[8] To obtain the resulting costs for electricity a deduction of the cost for heat from the total generation costs is made

When interpreting Table 4-4, it should be noted that the depreciation rates for the cogeneration units have been chosen lower than for the electricity only unit, not for technical reasons, but to reflect the economic perspective of an industry company building and operating the cogeneration units. Therefore, these electricity generation costs have to be compared with electricity purchased from the utilities, not so much with the costs of other new generation options. With respect to the social costs, the comparison therefore looks even better for the cogeneration units when calculated with the same useful life. Furthermore, particularly for the 20 MW unit it has to be taken into account that such decentralised generation will save investments in electricity network upgrades.

During this short study we are not able to make a detailed analysis of the cost estimates of the AMPERE Commission. But this seems to be necessary for a realistic economic assessment of cogeneration systems.

4.5 Centralised Fossil-Fuel Power Plants

According to the discussion about the fuel prices in relation to the coal fired power plants, the fuel cost estimates of gas fired plants are considered too high for the long term (after 2010), based on Prognos/EWI (1999). Furthermore, there are some assumptions concerning the efficiency of the future power plants, where we arrive at different results (cf. table 4-5). Especially the efficiency of the IGCC process (which is set to be 48 % at 2010 by the AMPERE Commission) seems to be underestimated. Comparable to ultra supercritical coal fired power plants, efficiencies of more than 50 % might be achievable.

Table 4-5: Overview of efficiency of electricity generation in fossil-fuel power plants

	average efficiency (today)	efficiency potential	realised projects	assumption for 2005
hard coal power plant	34,5 %		Rostock: 42,5 % Staudinger: 42,8 %	
advanced hard coal plant		47%		47 %
IGCC hard coal based		48,5 - 55 %	Puertollano, Buggenum: 45 %	
Pressurised coal dust combustion		52 %	1MW-pilot plant (Dorsten)	
lignite power plant	33 %		Schwarze Pumpe: 40,7 % Lippendorf: 42,3 %	
advance lignite power plant		43%	under construction: BoA Niederaußem: 45,2 %	44,5 %
advanced lignite power plant + innovative drying (BoA+)		50 %	pilot plant Niederaußem	50 %
IGCC/HTW lignite based		50 - 55 %	demo plant Berrenrath	
gas fired plants FC = fuel cell	38 %	58 - 62 % (CC) 60 - 70 % (FC)	HKW Leipzig, HKW Mitte (Berlin)	58 %
gas turbine	33 %	40 %		
high temperature fuel cell plus gas turbine (SOFC; SOFC-GT)	40 – 50 %	60 – 70 %		

Sources: (Heyn 1999; Elsen 1999; Schneider 1998; IKARUS 1994; Kaltschmitt, Fischedick 1995)

4.6 Network Integration of Decentralised Generation

The AMPERE Commission claimed that decentralised power plants are not able to provide some energy supply services (such as maintaining the voltage level by supplying reactive power or maintaining the equilibrium between production and consumption). That is not true. Already today, small cogeneration units with large hot water storage systems or additional coolers can contribute to power supply in times where additional electricity is needed. Using innovative communication technologies and control mechanisms, it furthermore is possible to link several decentralised systems to each other and to handle them like a bigger power plant with a high amount of flexibility. In Germany, the term “virtual power plant” has been created for such applications.

Decentralised units reduce the capacity needs for reserve units, which normally are necessary to ensure the provision of electricity demand if power stations have a breakdown. Following probability calculations (√1/n criteria) less reserve capacity is necessary with a higher amount of units per total capacity. Furthermore, with an increasing feed in of electricity on a decentralised level, the energy losses for transportation and distribution decrease, and the necessary efforts for the upgrade and retrofit of the grid units decrease. This has been acknowledged in the agreement between the German associations of industry and electric utilities on the principles of calculating the prices for access to the electricity network (the so-called “Verbändevereinbarung II”). According this agreement (point 2.3.3), decentralised cogeneration or renewable power plants (the latter only unless they receive the remuneration according to the feed-in law) will receive a bonus payment from the network owner. This bonus equals the prices for the avoided use of the higher voltage levels of the network. Similar considerations may have led the Flemish government to rule that electricity from renewable energies is completely exempt from the network prices.

On the other hand, it is true that in some cases (mainly cases of offshore wind for the transport to the shore; onshore wind in less densely populated areas) technical limitations of the transport and distribution network have to be taken into account for the installation of small units. But normally this problem can be solved by a limited reinforcement of the grid. Experiences from the northern part of Germany and especially from Denmark show that the integration of thousands of decentralised systems (here wind turbines) in the given structure of distribution network is possible.

It is obvious that the electricity output from some of the decentralised systems depends on meteorological aspects. This is especially true for wind and solar energy, but there are of course compensation effects (which lead to a decrease of fluctuations) using wind energy converters and solar panels at different places with different weather conditions. Biomass and cogeneration units can be combined with storage systems, for the fuel in the case of biomass and for the heat in the case of cogeneration. For these technologies as well as for hydropower, which is characterised by higher full load hours, the resulting problem with fluctuations caused by meteorological conditions is very small.

Beside decreasing fluctuations caused by compensation effects and an increase of flexibility using storage systems, weather forecasts systems enable the operator to make an estimate of the expected contribution of the decentralised units. He/she can prepare him-/herself and can work out a clear operating table for the other electricity generation units belonging to the power plant system.

Nevertheless, an intelligent cooperation of decentralised and bigger central power plants is necessary. Anyway, there are some tasks remaining for centralised plants. For example, frequency stabilisation as well as the guaranteeing of short circuit power must be realised with those bigger units.

In this context, several possibilities for increasing the flexibility of more decentralised power stations and enabling distinct contributions to energy services have been neglected or underestimated by the AMPERE Commission. But despite of this the Commission confirmed that an increasing share of decentralised units in the Belgium electricity system up to 22 to 25 % according to the total electricity supply could be handled. Taking the aspects outlined above into consideration, the integration potential of decentralised technologies might be higher. This is especially true if bigger plants like the planned unit at the BASF factory in Antwerpen are taken into account, where most of the electricity will be used on-site, thereby reducing the load in the national grid compared to the situation of centralised generation before.

Furthermore, from the potential identified by the AMPERE Commission only a smaller part (1.500 MW wind generators, of which only 500 MW onshore, 100 MW photovoltaic electricity) consists of technologies with a distinct fluctuation characteristic; offshore wind energy with 3.500 to 4.500 h/year should not really be considered as “fluctuating”. Studies carried out concerning the German electricity system show that even contributions of those fluctuating technologies (onshore wind, photovoltaic) up to 15 % can be integrated (cf. Fischedick 1995) without a resulting necessity of new grid structures and without the necessity to introduce new energy carriers as storage medium (e. g. hydrogen). This potential share will even be higher if offshore wind power plants are used, due to their higher full load hours.

5 Conclusions from the Methodological Analysis

Based on the analyses in Chapters 3 and 4 of the methods used by the AMPERE Commission to assess the electricity demand and supply sides, we now want to address the most important question: Is it possible to draw the AMPERE Commission's conclusions and recommendations from the results on the demand of electricity and by simply comparing the different electricity generation technologies in terms of potential and costs?

To shortly recall:

1. the AMPERE Commission recommends a strong role for demand-side management (DSM) to exploit the potentials of end-use energy efficiency. This is well justified, since any DSM resources that are cost-effective compared to the societal cost of the energy supply system should be used.
2. On the supply side of electricity, since the "plausible" potentials given by the AMPERE Commission for the low CO_2 options, i.e. cogeneration of electricity and heat, and renewable energies combined, are only equivalent to about 15 to 20 % of the expected future electricity demand, the Commission strongly recommends electricity-only gas-fired combined cycle plants; is divided over the new build of coal-fired electricity-only power plants; and recommends to keep the option for future nuclear power plant concepts open through continued public and private research.

However, our conclusion from the analysis we have presented in Chapters 3 and 4 is: **Because of severe methodological problems, is not possible to justify the recommendations for the future electricity generation options given by the AMPERE Commission based on the Commission's own results**. The reason is that both the methods used to derive these results, and the insufficiency of the results themselves, do not allow the recommendations to be justified.

Most notably, the AMPERE Commission has not developed an integrated, bottom-up scenario analysis of electricity demand and supply. Instead, the Commission took the forecasts of aggregated electricity demand more or less as given, analysed the potentials and costs of individual electricity generation options, and compared these to the demand forecast, without any system integration of demand-side energy efficiency and different supply-side options, and without a stringent analysis of policies to realise the different potentials. The effects of the integration of the European electricity systems were also neglected. The Commission **was therefore not able** to estimate the total needed investment and costs for the future Belgian electricity supply system in the internal European electricity market, nor the resulting total emissions. **An integrated bottom-up analysis of both electricity demand and supply would have been necessary** to first assess the baseline development in the "business-as-usual" case. Only if the baseline development has been assessed by such an analysis, will it, second, be possible to analyse the differences between this baseline and alternative futures that might "match the societal, economic and environmental requirements of the twenty-first century" (as it was stated in the objectives of the AMPERE Commission). Hence, **only such an integrated bottom-up analysis can deliver the results on which to base an informed policy decision**.

Furthermore, also many of the results of the AMPERE Commission on potentials and costs of individual electricity supply options seem to be insufficient. For instance, the electricity generation potentials of cogeneration and many renewable electricity generation options appear by far underestimated, while the costs particularly of some cogeneration options (e.g., gas-fired combined-cycle cogeneration plants) appear overestimated. E.g., for cogeneration, the 800 MW plant at the BASF factory in Antwerpen that is currently under construction will almost realise the additional potential for cogeneration declared "plausible" by the AMPERE Commission. It was not possible, however, to analyse this discrepancy in detail, since the AMPERE Commission does not provide enough detail to follow the methods how the potentials have been determined.

In contrast to the integrated analysis, the simple comparison of different electricity generation technologies in terms of potential and costs that has been used by the AMPERE Commission **cannot detect system integration effects**. These results of a simple comparison are therefore insufficient as a basis for recommendations. One important system integration effect that the AMPERE Commission thus neglected is: A stronger implementation of cost-effective demand-side energy efficiency, and cost-effective cogeneration options than in the baseline **will lead to considerable cost savings to society**. This surplus can be used to invest in a higher share of low-CO_2 electricity generation options (e.g., wind energy, less cost-effective cogeneration, biomass cogeneration) than in the baseline, although these options individually may be more costly than large fossil-fuel generation plants. In total, much lower CO_2 emissions might be reached in such a scenario than in the baseline scenario, with the same or only slightly higher total costs.

It is therefore not needed to artificially limit the potentials of cogeneration or renewables that are recommended to achieve by 2020 to such low levels based on a cost argument and considerations like "we cannot afford more of this costly resource", as the AMPERE Commission seems to have done. Furthermore, the arguments of the AMPERE Commission that a high share of decentralised resources will lead to network constraints or additional investments are contrary to the experiences in other countries, as e.g. our Table 4-3 above has revealed. Rather, decentralised cogeneration, photovoltaics and biomass plants, and to a lesser extent, wind energy will reduce the need for upgrades in the electricity transmission and distribution network.

Another systems integration effect that the AMPERE Commission failed to take into account is the integration of the European electricity markets. Belgium will not have to cover all its electricity demand from domestic production in the future. Belgium can, e.g., benefit from the much higher offshore wind potentials available in the Netherlands or Denmark, if the international transmission network allows, and if, e.g., internationally recognised certificates for renewable electricity will facilitate the cross-boarder trade of such electricity. Also, the Belgian CO_2 reduction targets will not have to be met by each sector alike. Since the specific CO_2 emissions per unit of energy of the Belgian electricity sector are relatively low, the total emissions reductions it can achieve have to be determined in the context of an internal Belgian "burden sharing" with other sectors, e.g., fossil fuels used directly to heat buildings or fuel industry processes, and cars.

6 Recommendations for Further Policy Analysis

Based on our conclusion in Chapter 5, that the methods and results of the AMPERE Commission are insufficient to be a basis for an informed policy decision process, we will in the final chapter give recommendations for a methodology that is able to create such a basis. Again, we will first look at the methods for the electricity demand and demand-side energy efficiency, and electricity generation options separately. In the final section, we present the method for integrating supply-side and demand-side.

6.1 The Demand Side

6.1.1 General Method of Bottom-up Analysis

A bottom-up analysis of the electricity demand by sector and end use is absolutely necessary to provide the basis for analysing the technical and economic potentials for increased demand-side energy efficiency and the share of these potentials that could be achieved by different policy instruments[9]. Furthermore, such a bottom-up analysis is also needed in the baseline scenario to achieve a credible basis for the most plausible future development of electricity demand. In Chapter 3.1, we already mentioned the example of energy policy analyses in Germany: Such a bottom-up approach has been used, e.g., by the Prognos AG and others since the mid-1980ies in their periodic updates of the “business-as-usual” scenario made for the German Federal Ministry of Economy (cf., e.g., Prognos/EWI 1999 for the latest revision), and is the standard technique also in the scenario analyses of the Wuppertal Institute and other German institutes. Only if already the baseline development has been assessed with a bottom-up scenario, will there be a good basis for analysing alternative scenarios.

Such a bottom-up scenario analysis would mean to first allocate the electricity consumption to the end uses for which it serves in each sector, e.g., space heating, water heating, space cooling, food cooling, lighting, ventilation, pumping, motive power for production processes, cooking, dish washing, clothes washing, office equipment etc. For doing this, the consumption needs to be calculated based on specific energy consumption for each unit of energy service, e.g., the office floor space occupied, the number or volume of goods produced, or the number of equipment used for a certain end use (e.g., washing machines). These numbers have to be related to the economic drivers for energy consumption, like the value of industrial production, the number of employees in the service sector, or the number of households.

In each of a number of alternative scenarios, the economic drivers, and the relations between drivers and units of energy service are usually kept the same. However, the values of the specific energy consumption for each unit of energy service are the subject to

9 The only bottom-up study, at least of economic potentials for energy efficiency, that we know of for Belgium is the report by STEM (1995).

change between alternative scenarios. E.g., in the baseline scenario, the annual energy consumption of refrigerators will be extrapolated into the future from historic developments, whereas in an energy efficiency scenario, the best technology available today, or even more efficient technologies of the future may be chosen.

6.1.2 Method for Analysing Demand-Side Energy Efficiency

In principle, an attempt to quantify the potential contribution of improved end-use energy efficiency to a sustainable future energy policy and system should follow a **three-step bottom-up approach**. This is a part of the integrated bottom-up approach described in Chapter 6.3.

1. Estimate the *total technical and economic potential* of energy efficiency for a range of technologies/end-uses and sectors, e.g., look at energy-efficient lighting separately for the domestic, commercial, and industrial sectors, etc. For each technology area, estimate which percentage of the energy consumption can be saved through more energy-efficient technologies *compared to the baseline*, and at which cost. This potential energy saving is cost-effective to society, if the costs of conserved energy (levelised annual costs of the extra investment compared to the baseline technology, divided by the annual extra savings) are lower than the long-run energy system costs for supplying the energy.

2. In many cases, the opportunity of cost-effective energy efficiency measures is connected to the normal turnover of energy-using equipment, or to normal refurbishment cycles. In these cases, it may cost only a little more to buy the most energy-efficient model out of a range of products delivering the same service. Therefore, the next step is to *estimate the rates of turnover and refurbishment* for such technologies. For other technologies, for which an early replacement or upgrading is possible (e.g., replacing incandescent lamps by CFLs, or adding a variable speed drive to an existing electric motor), the *rates at which industry could deliver* these technologies has to be estimated. As a result, the rate can be estimated at which the total potential from step 1 becomes, for technical and economic reasons, available over time.

3. Such *economic* potentials exist because of a large number of market barriers, which prevent energy users, building owners and developers, and suppliers of energy-using technologies from fully implementing the potential which would be economic for society. Therefore, in the baseline, only a smaller part of the full technical and economic potential will be realised. Policy actions can help the economic actors to overcome those barriers. The third and final step is therefore, to analyse how much of the technical and economic potential that exists compared to the baseline can actually be realised by which policies.

To give **an example**: such a process was carried out in a recent study by the Wuppertal Institute on behalf of the Federal Minister for Environment, Protection of Nature and Reactor Safety in Germany (Wuppertal Institute 2000). The overall approach is described in Chapter 6.3; here we give more details on the demand-side analysis.

The figure below shows how the economic and technical potential for electricity end-use energy efficiency becomes available over time ("total potential" for 2005, 2010, 2015, 2020), i.e., the result of step two of the three-step approach. This is based on a total of 19 technology areas; a similar approach was taken for heating end-use energy efficiency.

In the third step, the Wuppertal Institute estimated the percentage of the potentials that can be achieved through certain policies, with three levels of increasing political realisation intensity. Other experts were also asked about their opinions on the effect of these policies. The figure also shows the results of this analysis.

The three levels of increasing political realisation intensity are characterised as follows:

+ contains a mix of "carrot" and "tambourine" policies, that are considered to not need a lot of political debate, although sometimes a certain level of extra funding: targeted and general information schemes, labelling, energy audits, co-operative procurement, and other energy efficiency programmes and services.

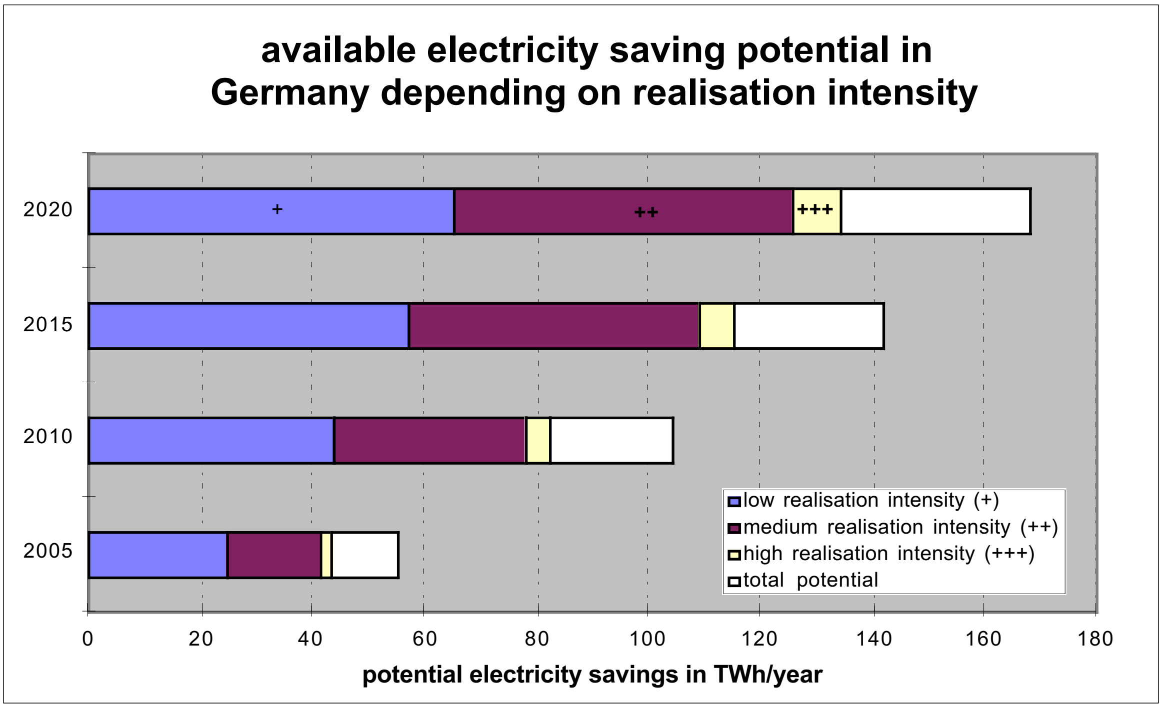
++ adds either mandatory or negotiated "top-runner" or "best practice" energy efficiency or technology standards, i.e. some "soft stick" policies to the mix. It is, however, considered that the policy mix of standards with the "+ level" policies that assist energy users, building owners and developers, and suppliers of energy-using technologies to achieve the standards, is making the whole package favourable and acceptable for market actors and policymakers.

+++, on the other hand, tries to impose action on the market actors by mandatory energy efficiency standards or prohibition of some inefficient technologies ("hard sticks").

As the example shows, a mix of "carrots", "soft sticks" and "tambourines" is estimated to realise almost as much of the potential as a policy that would rely on "hard sticks" but probably face much higher political resistance.

Such an approach with three different levels of increasing political realisation intensity may not always be needed, it is **given here just as an example**.

Figure 6-1: An example for the results of a bottom-up analysis of demand-side energy efficiency policy



Source: Wuppertal Institut 2000

6.2 The Supply Side

Since it is not possible to find out how the AMPERE Commission analysed and developed the potentials for cogeneration and renewables, we just want to briefly describe the general bottom-up methodology how to do this in a more comprehensive analysis. It can be assumed that some of the studies we cited in Chapter 4, which have yielded higher estimates for the potentials of cogeneration and renewables than the AMPERE Commission, have used such a bottom-up methodology. However, this should be checked, and if necessary, a new up-to-date bottom-up analysis of the potentials for cogeneration and renewables in Belgium should be carried out.

As described for the demand-side in Chapter 6.1.2, after the analysis of energy generation potentials and costs, the following step is the analysis of policy instruments, using expert estimates about the share of the potential that can be realised by these policies.

6.2.1 Potentials and Costs for Cogeneration

Since it is not possible to analyse all possible individual sites for cogeneration, it is necessary to analyse the potentials and costs for a number of typical plants, e.g., combustion engine combined heat and power (CHP) plants of 5, 15, 50, 100, 200, 500, 1000 kW_{el} etc. or combined-cycle CHP plants of 20, 50, 100 MW_{el} etc. Furthermore, it is necessary to distinguish between the use of cogeneration for producing space heat for district heating, mainly for residential buildings or for office buildings; space heat and cooling for individual office buildings; or process heat (and cooling) for industry. The differences are mainly in the appropriate technologies, depending on the temperature of the heat that is needed, and in the load duration curves of heat and cold demand. Then, looking at the sizes of cities and towns and their population density, and at the sizes and heat demands of commercial and industrial facilities, one can attribute one of the typical CHP units to each of these geografically isolated potential sites. Counting the numbers of sites per typical CHP unit leads to the total potential. The cost has to be calculated once for each typical unit and typical "user".

6.2.2 Potentials and Costs for Renewables

The method for determining the costs and potentials of renewable electricity generation options is in general similar to that for CHP units. The difference lies of course in the definition of potential sites:

- for wind energy, it is the available areas (e.g., respecting minimum distance to dwellings) and average wind speeds;
- for biomass, it is the availability of the biomass (wood, manure etc.) at different sites;
- for photovoltaics, it is mainly the area and orientation of roofs and façades that determines the potentials.

6.3 Integration of Demand Side and Supply Side

6.3.1 Integrated Bottom-Up Scenario Analysis

In order to generate a reliable basis for informed decisions on the future energy policy in Belgium, **we recommend the development of a policy oriented** (goal: identification of necessary policy actions) **and discourse oriented** (goal: discussion of scenario results with all relevant groups) **integrated demand and supply side bottom-up scenario analysis for Belgium**. In Germany, for example, such scenario analyses were used to determine the policy goals, doubling the share of renewable energies and cogeneration by the year 2010. In addition, they build the basis for the discussion about the compatibility of nuclear phase out strategies and climate protection targets.

In Germany, in the energy sector, scenario analyses are often used as a helpful tool for policy-makers. Scenarios are different from forecasts; the latter normally show a "business as usual" future path extrapolated from empirical experience gained from the past. Scenarios enable a quick view of different future paths which are determined by specific assumptions (e.g. economic and population growth rates, climate protection targets, agreements about the use of nuclear or coal power plants). Primarily it is the task of such analyses to identify the areas where additional activities in comparison to a "business as usual” development are necessary. Secondly, they can help to quantify the magnitude (or the range of magnitude) of the need for action (e.g. CO_2 emission goals for each sector or for each sub-sector of industry), how can transport and industry contribute to climate protection, and what has to be done in the other sectors (e.g. electricity generation, households, services sector, etc.). Scenario analyses provide the necessary basis for the discussion of policy actions in each sector as well as for more comprehensive policies.

Concerning energy scenario development, **several methodologies** can be distinguished. For the purpose outlined above, **a heuristic approach** allowing a **consistent** system integration will be the most appropriate one.

- A consistent heuristic approach in the first step introduces policies to realise additional energy efficiency potentials compared to the baseline, as derived in the demand-side bottom-up analysis (cf. Chapter 6.1).
- It then adds the implementation of supply-side resources from the supply-side bottom-up analysis (cf. Chapter 6.2), as the analyst, or an expert or stakeholder panel (cf. next section) considers plausible and feasible based on specific policy frameworks and instruments, not just based on generation costs of individual technologies.
- In the final step, the total primary energy consumption, emissions, and costs for the scenario are calculated from the fuel mix that has been generated.

As already mentioned in Chapter 5, such an approach **is superior to a simple economic optimisation model** since it can model system integration effects and the effect of policies. E.g., a stronger implementation of cost-effective demand-side energy efficiency, and cost-effective cogeneration options than in the baseline will lead to considerable cost savings to society. This surplus can be invested in a higher share of low-CO_2 electricity generation options than in the baseline, although these options individually may be more costly than large fossil-fuel generation plants. In total, much lower CO_2 emissions might be reached in such a scenario than in the baseline scenario, with the same or only slightly higher total costs. Alternatively, if the total achievable potential is higher than needed to achieve the national CO_2 reduction target, it is possible to determine the least-cost scenario for achieving the target, combining cost-effective (i.e. net gain) and low-cost options with this integrated, expert knowledge-based, bottom-up scenario modelling technique.

Therefore, we recommend this type of modelling **instead of partial equilibrium models** (such as PRIMES or MARKAL), which use a simple economic linear optimisation to determine the mix of resource options[10]. Because of their purely mathematical problem-solving algorithm, such models will automatically throw out options that are “not cost effective”, since their picture of the energy system is usually highly aggregated. They usually only have one typical average cost for one technology or even energy demand sector. They therefore have principal deficits in modelling particularly demand-side energy

10 Cf., e.g., the study “How to achieve the Kyoto Target in Belgium – modelling methodology and some results” from KU Leuven (2000) as an example of such a partial equilibrium model approach.

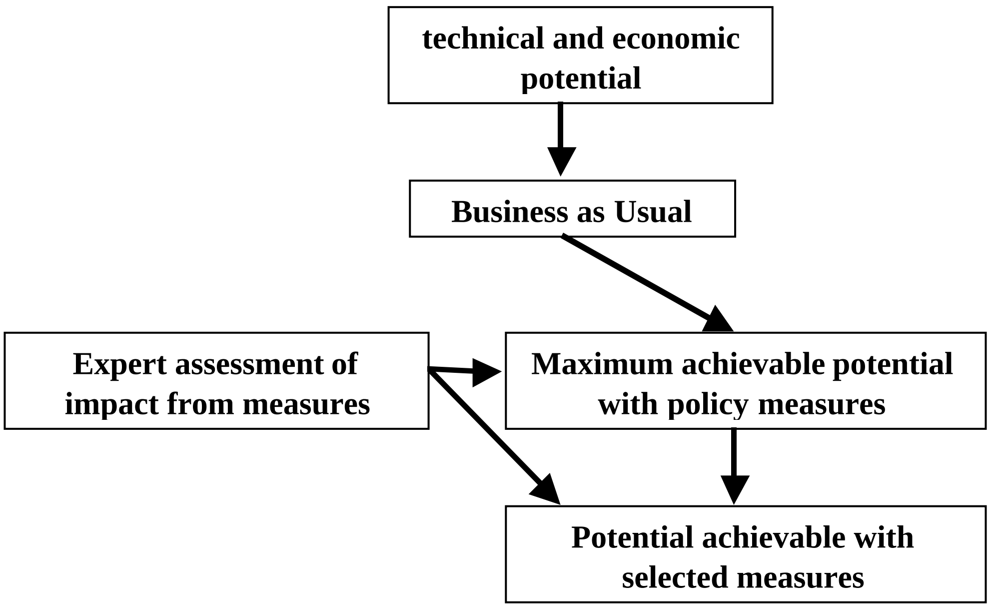
efficiency and decentralised electricity generation options, since the costs of these options are typically site dependent and vary over a wide range. In most linear optimisation models, it depends on the average cost of the technology if it will be either fully used or not used at all, instead of using at least the cost-effective part of the technology. In particular, the economic optimisation should not be done based on the so-called costs of CO_2 reduction, since this concept has serious methodological flaws (cf. Appendix).

6.3.2 An Example for a Heuristic Scenario Approach

In the Wuppertal Institute, we use a technically-oriented, bottom-up scenario approach. As opposed to many other scenario generation tools, the model can be characterised by a high specification level concerning technological processes, on the supply side as well as on the demand side. Apart from **technological analysis** (e.g. potential analyses for the available contribution of renewable energies), the second main input of the model is **expert knowledge** concerning the definition of **suitable policy measures**. Comparable to the approach of Delphi interviews, the methodology gains from the implementation of different expert assessments.

The methodological principle of the Wuppertal Institute’s modelling approach is outlined in the following figure. The starting point of the scenario development is to determine the technical and economic potential of several technologies (e.g., improvement in the potential for insulating buildings, potential for electricity generation from wind energy). The second step is to analyse, which part of the potential outlined above is likely to be realised in a “business as usual” path for the future, i.e. autonomously, and which further part of the technology’s potential can generally be achieved by additional policy measures. For this, the knowledge of expert groups becomes particularly important.

Figure 6-2: The Wuppertal Institute’s modelling approach of expert assessment (general overview)



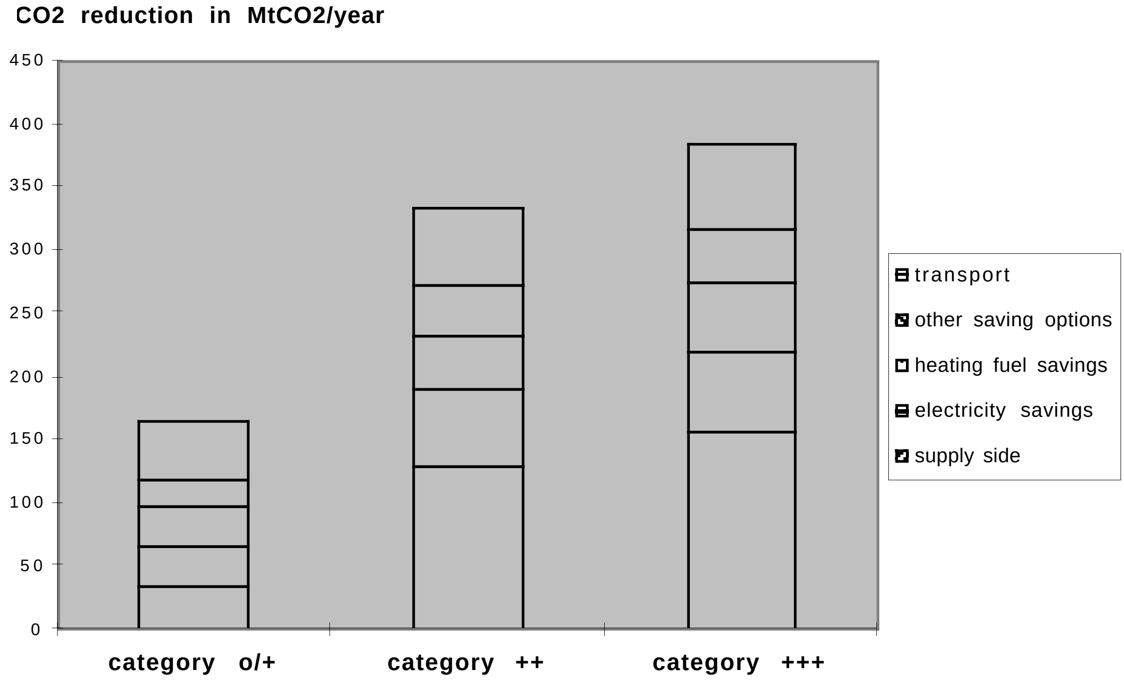
In the approach of the Wuppertal Institute, the experts not only have to make assessments about the share of a technology's potential which can be generally addressed by policy measures, but also to discuss which element of this share can be realised following different degrees or intensities of policy action. In the scenario model we distinguish in each sector between a policy instrument with low (o/+), medium (++) and high (+++) intensity (cf. Chapter 6.1.2 for more detail on the demand side). According to the political framework and the environmental targets, it is more or less difficult to implement instruments of high intensity. In other words: choosing a future path concerning a sustainability scenario (including climate protection), the political framework allows a larger degree of technological potential to be realised than could be assumed under "business as usual" conditions. It is the important task of the scenario model to make clear which combination of policies of which intensity is necessary to achieve the targets.

If enough policy actions have been developed and discussed, scenario analyses enable the user to gain direct assessments of their impacts. That is possible because they draw a theoretical picture of the reality and include all relevant transformation processes as well as interactions between the different processes.

In Germany, the recently published national climate protection programme (based on a government decision of November 2000) is at least partially an example of such a policy-oriented approach. In this programme, policy instruments for every energy relevant sector which have been implemented before and which will be implemented in the next years with a high amount of certainty have been collected in a scenario. Within this scenario especially the implications of these instruments concerning the reduction potential for CO_2 have been assessed. According to the resulting difference between the German climate protection goal (reduction of CO_2 by 25 percent up to the year 2005 compared to 1990) and the scenario estimations, additional fields of action have been identified and additional policy instruments and actionshave been addressed. However, the consistency and systems integration in the development and choice of these additional measures, as well as the methods to assess the effects of individual instruments/actions could be improved further.

For the longer term, the next figure based on the same methodology shows assessments for policy measure implications distinguishing between different implementation intensities. It is taken from the same study, from which the example for the demand-side energy efficiency potentials and policies in Chapter 6.1.2 was taken. Here, we present the results of the integrated scenario that combines the electricity energy efficiency potentials shown in figure 6-1 above with the policy-based potentials from four other fields of policy action for the year 2030. The figure thus shows how much CO_2 reduction could in total be achieved in Germany by the year 2030 with three different levels of policy intensity. The CO_2 reduction is calculated vs. a baseline that includes the nuclear phase-out.

Figure 6-3: CO_2 reduction options by different sectors depending on intensity of policy measures in the year 2030 compared to a “business as usual” strategy



Source: Wuppertal Institute 2000

The policy instruments include:

for category o/+: information programmes, voluntary agreements (e. g. for the limitation of stand by losses of electrical appliances for offices or households or average consumption of cars), grants (e. g. for an improvement of the insulation of existing houses)

for category ++: bonus systems (e. g. for renewable energies or cogeneration), road pricing for commercial transportation, combinations of energy efficiency standards, information, motivation, training, and financing instruments (more stringent rebates/grants, loans, third-party financing)

for category: prohibitions for electric storage heating systems, quota systems (e. g. for cogeneration), limitation of electricity consumption by law, obligations for retrofitting of old heating systems

The technology areas include:

transport: fuel efficiency of cars, no reduced transport vs. the baseline, nor a change in modal split

other saving options: mainly industrial process heat

heating fuel savings: thermal insulation, better boilers and controls

electricity savings: all kinds of technologies and end-uses

supply side: mainly cogeneration (gas and coal) and renewables, some gas-fired combined-cycle plants without cogeneration

Summing up, we think that for the political discussion in Belgium it will be very helpful to carry out comparable investigations.

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Appendix: Critical Comments on the Use of the 'Specific Costs of CO_2 Reduction' as a Criterion for the Selection of Energy Resources

Stefan Thomas (Wuppertal Institute)

1 Background

The following discussion is based on an optimisation problem, which is at least two-dimensional: the reduction of CO_2 emissions has to be maximised and, simultaneously, the costs of the supply of (genuine) energy services supply should be minimised.

In a first approach, the multitude of different technical options of energy supply or end-use energy efficiency can be assorted separately with respect to these two criteria. This will provide one ranking of options based on the costs of useful energy supply or of conserved energy, p (in EUR/MWh), and a second ranking based on the specific CO_2 emissions e related to energy (in t CO_2/MWh).

The potential of a CO_2 reduction option compared to the baseline thus can be derived from the comparison between the specific emissions e and the specific emissions e_0 of a "traditional" or "backstop" technology, multiplied by the "supply potential" (in kWh/year) of the reduction technology. Usually, a coal fired steam turbine plant is assumed as such a "traditional" or backstop technology (BST) in the electricity sector, and an oil-fired boiler in the heat sector, respectively.

A comparison between the total cost (system cost) p of the reduction technology and the system cost p_0 of the BST leads to the first economic classification of different CO_2 reduction technologies: those, which have a positive economic benefit in addition to the CO_2 reduction – with $p < p_0$ being cost-effective from a total resource cost perspective -, and those, which produce net costs for the economy ($p > p_0$).

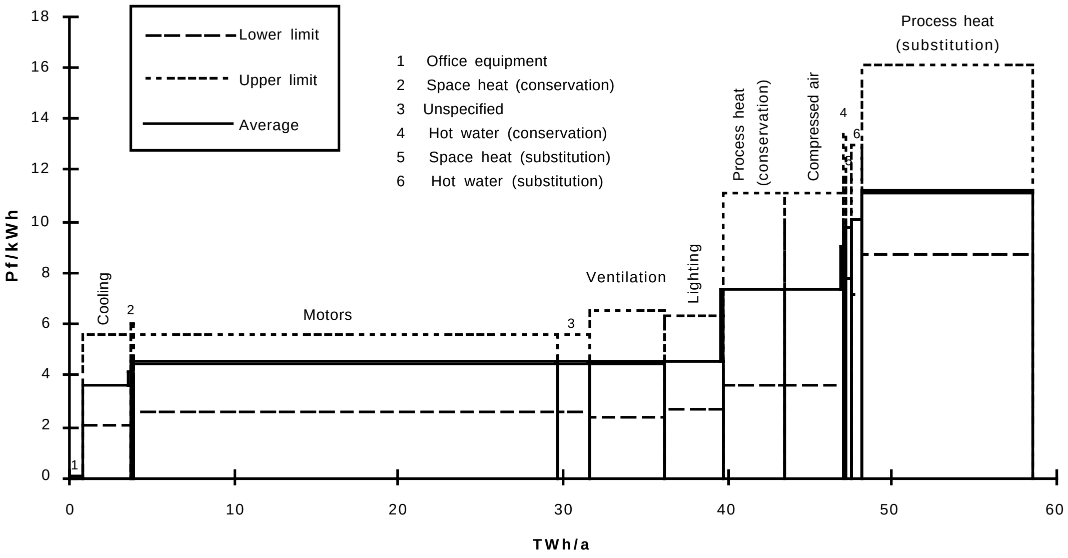
2 Visualisation using "Supply curves"

For a better visualisation, **similar options** might be illustrated as a step curve with a **ranking** of the energy supply cost versus their energy supply or saving potential, or versus their absolute CO_2 reduction potential compared to the backstop technology.

This is called a **supply curve**, e.g., for energy efficiency technologies or programmes that conserve electricity. The big advantage of supply curves is that they allow to detect the biggest and least-cost potentials to screen with one glimpse.

The following figure shows an example of such a supply curve of conserved or substituted electricity.

Figure 1: Supply curve of electricity conservation and substitution for the industrial sector in Germany (Consumption 1993: 205,8 TWh)



Source: own calculations based on Stadtwerke Hannover/Öko-Institute/Wuppertal Institute 1995: Integrated Resource Planning, The Hanover Case Study, Hanover/Freiburg/Wuppertal

3 Fundamental Problems of Ranking Procedures and Supply Curves: Methodological Limits of Isolated Comparisons between Technologies

Problems will arise, if different technologies and options have to be compared with each other, e. g., electricity end-use efficiency and gas-fired combined cycle power plants. Here, two principal problems occur:

1. Large scale technologies, above all electricity generation plants, usually have relatively well-defined supply costs. On the other hand, all decentralised options, such as energy efficiency measures, combined heat and power, and renewables, show a broad spectrum of supply costs (cf supply curve of saved electricity in figure 1 as an example). If not only energy efficiency potentials are to be compared with energy efficiency potentials, or coal-fired power plants with coal-fired power plants, but a variety of different technologies are to be compared with each other, usually detail will be sacrificed for the sake of simplicity of the visualisation, by defining one or a few representative average cases, such as “electricity conservation“, “wind energy“, “small photovoltaic generators“, “small scale CHP package system“.

Consequence:

If the supply curve compares typical average individual technologies, the selection of the cost parameters might be used to **manipulate** the results considerably. Particularly, an option might be excluded although it provides many cost-effective individual cases, if its “average“ appears unattractive compared to the “average“ of other options. Thus, the “step curve“ should rather be replaced by a “saw-tooth curve“, which is more realistic, but by far less simple and suggestive than the step curve.

2. The **potentials** usually **are strongly interdependent or even competing**. For instance, electricity saving diminishes the potential for combined-cycle power plants, CHP package systems based on natural gas and solar heating are competing technologies for local heat supply. Furthermore, a backstop technology might be altered itself, if, e.g., the average electricity generation fuel and power plant mix is defined as a BST. It is thus not sufficient to combine in a computer model single steps or parts of the curve, which represent single technologies, to a total supply curve.

For both reasons, it is necessary to calculate **consistent, non-contradictory bottom-up energy scenarios**. The resulting total cost and total emissions of the energy system can be analysed, with subsequent iterative optimisation of the scenarios.

If, on the other hand, a selection between different options is based on the simplified comparison by means of cost values from supply curves, faulty decisions might be the consequence.

4 Special Problems of Specific CO_2 Reduction Costs as a Selection Criterion

The wish for being able to compare between options with different specific CO_2 reductions (e.g., electricity conservation and thermal solar systems), and thus for a reduction of the two-dimensional optimisation problem into a one-dimensional optimisation problem, led to the idea of mathematically dividing the energy supply cost by the CO_2 reduction with respect to the BST. In this way, the specific CO_2 reduction cost is created as an index, with the objective to provide „at first sight“ the most efficient option by ranking these indices.

This objective cannot be fulfilled by the specific CO_2 reduction costs.

1. The **fundamental restrictions** to a ranking – with or without illustration as a cost-potential curve - of **different options** based on average cost data are also valid here, analogously to the discussion in Chapter 3.

2. A **mathematical flaw** exists, and

3. the options for manipulation and faulty decisions as discussed in Chapter 3 become more severe, if the CO_2 reduction costs are based on **individual economic perspectives** instead of a total resource (societal) perspective.

re 2 – the mathematical flaw

For values < 0, the mathematical function of the CO_2 reduction costs will deliver **no valid statement about the „cost efficiency“ of different options**. This is of particular significance, if the numerator is formed by the net costs of an option relative to the costs of the backstop technology. Resources, which are cheaper than the backstop technology, will thus lead to negative CO_2 reduction costs. In this case, the construction of the CO_2 reduction costs as a mathematical fraction results in a preference of resources with lower CO_2 reduction, because for the same costs (same numerator) the magnitude of the fraction increases for decreasing CO_2 reduction.

The following schematic example will illustrate this problem. Two different resources will be discussed:

	Resource 1	Resource 2
relative energy supply costs $p-p_0$ (EUR/MWh)	- 10	- 5
CO_2 reduction e_0-e (t/MWh)	1,0	0,2
CO_2 reduction costs (EUR/t)	- 10	- 25

Obviously, resource 1 has to be preferred in this case, because the economic net benefit **and** the CO_2 reduction are higher compared to resource 2. The CO_2 reduction cost criterion $k_2 < k_1$, however, leads to a faulty decision, namely to the selection of resource 2.

This mathematical flaw restricts the CO_2 reduction cost concept to the economically unattractive area of resources, which cause net costs in the total resource cost perspective. In the attractive field of those resources, which combine climate protection with economic net benefits, the concept leads to completely wrong priorities. It prefers options with low CO_2 reduction potentials to those with high reduction. Particularly, a useful comparison between heat and electricity-based options is not possible with this concept.

re 3 – individual economic perspectives

If the CO_2 reduction options are evaluated from individual economic perspectives instead of a total resource perspective, the CO_2 reduction costs loose any significance. Misunderstanding or even misuse might be the consequence. Depending on which conditions are assumed for the calculation, any desired result can be substantiated. An example will illustrate this:

Example: utility electricity conservation programme with rebates

Assumptions and results are listed as “costs”, because they would be included as such in the specific costs of CO_2 reduction. Thus, negative numbers signify benefits, ergo cost-effectiveness.

1	total resource costs	30 EUR/MWh(costs of conserved energy	
1a	*of these, technology costs*	*20 EUR/MWh* in EUR per MWh saved)	
1b	*of these, programme costs*	*10 EUR/MWh*	
2	rebates	10 EUR/MWh	
3 = 1b+2	total utility costs	20 EUR/MWh	
4	avoided costs utility	-50 EUR/MWh	
5 = 1+4	**net costs to society**	**-20 EUR/MWh**	i. e., net *benefit* 20 EUR/MWh
6 = 3+4	net costs utility	-30 EUR/MWh	i. e., net *benefit* 30 EUR/MWh
7	lost revenues utility	80 EUR/MWh	net of taxes
8 = 6+7	losses utility	50 EUR/MWh	without additional funding from a favourable political framework
9	losses utility	-4 EUR/MWh	i. e., profits with a favourable political framework

Favourable political framework compensates utility’s losses and concedes 20% of the net benefit to society (i. e., 20% of no. 5 =20 EUR/MWh) as a profit.

Which „costs“ are now to be assumed for this programme? The programme is highly attractive from a total resource perspective, as it yields a profit of 20 EUR per saved MWh.

Nevertheless, any positive or negative evaluation of this programme is possible with the CO_2 reduction cost concept: It merely depends on whether the utility’s investment (20 EUR/MWh costs), or its cost savings compared to the long-term electricity system costs (30 EUR/MWh savings, i. e., negative costs), or the programme’s effect on the profits without a favourable political framework (50 EUR/MWh losses, i. e., costs) or with a favourable political framework (14 DM/MWh profit, i. e., negative “costs“ in the CO_2 reduction costs) is put on.

Something else becomes evident: If for all options only the investments are focussed on without taking into account the corresponding energy cost and capital cost savings for the backstop technology, the impression might be created that climate protection is something that “costs money“. Furthermore, resources which are dominated by the investments (end-use energy efficiency, renewables, partly CHP systems) will be systematically discriminated compared to traditional supply technologies with low specific investment costs (e. g., combined-cycle power plant).

5 Conclusions

If a preselection of resources based on cost criteria has to be done at all, it should **not** be carried out by means of the seemingly simple specific CO_2 reduction cost concept. Instead, the economic efficiency and the CO_2 reduction should be analysed separately, and should remain two different criteria.

For the assessment of the economic efficiency, the costs from the total resource perspective, relative to the avoided costs of the „backstop system“, are relevant. All measures, which are cost-effective compared to the backstop system, should be realised in any case. If the individual economic feasibility is hindered by the political framework, the actors (e.g., utilities) are advised to engage themselves for a modification of the framework in a way that all options, which are cost-effective from a total resource perspective, should also be economically attractive from the individual business point of view (favourable framework from energy policy).

For those measures, which cause real additional costs compared to the backstop system, a decision, as to which extent the different resources might and should be developed, should be based on total resource costs (EUR/kWh), CO_2 reduction, reduction of other pollutants, and further criteria (e.g., long-term market entry as a target).