III Assessment of Investment & Financial Flows for mitigation in the energy sector

3.1 Introduction

The energy sector is the primary source of global greenhouse gas (GHG) emissions, currently accounting for about 70% of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions combined.[12] Over 95% of energy-related GHG emissions come from the combustion of fossil fuels[13]. The energy sector exhibits also the highest rate of emissions growth in most individual countries. Moreover, energy sector emissions are growing faster in rapidly industrializing countries.

Energy sector mitigation options can reduce GHG emissions while contributing to sustainable development and improving standards of living through a number of potential co-benefits.[14] Co-benefits of mitigation measures may be reflected in social, environmental and economic indicators as shown in the following examples:

- Local air pollution abatement and reduced damages to human and ecological health may result, for example from the incorporation of cleaner energy sources and technologies.
- Balance of trade and energy security improvement are derived from the use of locally available and/or cheaper energy sources as well as from more efficient energy generation or end use technologies.
- Facilitate access to modern energy services. This is the case when electricity substitutes for other energy carriers with lower efficiency and higher associated environmental and health risks (e.g., where biomass burning was the main source for household cooking, lighting and heating services).
- Reduce cost of energy and thus widen access to affordable energy.

---

[12] Based on data in IPCC (2000) and IPCC (2007): IPCC, 2000, *Special Report on Emissions Scenarios*, N. Nakicenovic and R. Swart (eds.), Cambridge University Press, Cambridge, United Kingdom, 570 pp. Accessible at: http://www.ipcc.ch/ipccreports/special-reports.htm IPCC, 2007, Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O.R. Davidson, P.R. Bosch, L.A. Meyer (eds.), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 851pp. Accessible at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

[13] Based on data in EDGAR (Emission Database for Global Atmospheric Research), accessible at: http://www.mnp.nl/edgar/

[14] Co-benefits are referred to as “positive externalities” in Chapter II. The term “co-benefits” is used here because the term is typically used in the GHG mitigation literature.

- Enlarge employment opportunities through new production capacities and service subsectors, for example, via jobs involved in new power facilities, electricity distribution services and associated construction and maintenance). Expansion of renewable energy facilities could also lead to green job creation.

It follows from the above that some mitigation measures may result in net savings due to reductions in fuel requirements. That would be the case, in particular, if fuel savings derived from a mitigation option (e.g., an energy efficiency improvement programme) over a certain period more than compensate for the associated investment (e.g., in more efficient electric equipment) and operation and maintenance costs. In addition, mitigation measures that involve infrastructure investments will have long-term GHG and non-GHG benefits due to the long lifetimes of infrastructure capital stock. Such investments include investments in energy supply infrastructure (e.g., new power plants), and energy end-use infrastructure (e.g., energy-intensive industrial production facilities, buildings, and transportation infrastructure).

Given the time and resource constraints of the I&FF assessment exercise, it may only focus on a limited number of key mitigation options applicable in priority energy subsectors rather than aim at estimating the full cost of implementing all possible mitigation options. This implies (as reflected in the step by step description below) that the assessment team will have to scope and screen mitigation options to be included in the assessment exercise according to the host country development needs and strategies as well as other relevant criteria from the country's standpoint (e.g., cost effectiveness; GHG mitigation potential, etc.). Before approaching this scoping and screening step it is important to keep in mind the wide variety of mitigation options available in the energy sector. These options may encompass measures to be implemented at different energy supply and demand side subsectors. An illustrative list of energy sources and carriers, conversion and end use technologies as well as end-use sectors that may be useful to define the relevant subsectors is provided in Figure 3.1. Mitigation options will typically involve switching from technologies or energy carriers with high GHG emissions to cleaner alternatives, measures to improve end users' energy efficiency or reducing fugitive emissions from energy distribution or transportation services.

Note that some energy related mitigation options will be excluded to avoid double counting. For example, that is the case of mitigation options associated with the production of woody and agricultural biomass for biofuel production (e.g., to reduce N_2O emissions from fertilizer use). These can be seen mainly as forestry and agriculture mitigation options.

The parts of Figure 3.1 that are relevant to an IF&FF assessment in a particular country is entirely country-specific, as discussed below in section 3.2. Each country involved in the assessment will have to choose among a large number of mitigation options that may be implemented in the energy supply side (or a specific supply subsector such as the extraction of primary fuels, processing and transformation to secondary and tertiary forms of energy, etc.) As well as in various end use sectors. End-users include those that utilize (or "demand") energy, such as industrial production, and residential energy use.

If previous analyses (such as Technology Needs Assessments, strategic mitigation studies or National Communications) already identified a list of priority mitigation options that is still valid for the country's current conditions and development strategy the assessment team's main task will consist of estimating the incremental I&FF and O&M costs of implementing those options and their policy implications.

If no valid list of mitigation priorities is available, the team will have to build it on the basis of the guidance provided below.

Just to provide a few useful examples, it is worth mentioning that the energy supply subsectors may adopt mitigation measures that reduce either:

1) Combustion emissions from the energy producing and fuel extraction and conversion industries (e.g., by substituting fuels with high GHG emissions for cleaner options in power plants, adopting cleaner technologies as when investing in combined heat and power facilities, etc.); or
2) Fugitive emissions, for example from the extraction, processing, storage, and transport of fuels

For their part, mitigation measures implemented on the energy demand side (end-use) subsectors reduce either energy demand via higher efficiency in end use technologies for primary, industrial or service (transportation, energy, building, etc.), production (e.g., higher efficiency boilers and appliances), or via the substitution of fossil fuels (e.g., domestic and industrial solar water heating).

More generally, reductions in energy-related GHG emissions can be achieved through either improved efficiency in energy use or production, or reducing emissions per unit of energy production through technological or energy source changes. Table 3-1 lists mitigation measures for each of these categories of measures. More specific mitigation measures are discussed below in section 3.2.

Figure 3.1. Scope of the Energy Sector (Demand and supply-side subsectors, energy carriers and sources as well as production and end-use technologies)

Resources	Conversion and Process Technologies	Energy carriers	End use technologies	End use subsectors
Coal	Combustion/CHP	Coal	Industrial processes	INDUSTRIAL Production Space Heating Lighting
Oil	Liquefaction	Refined Liquids	Industrial heat	
Natural Gas	Coal Wash and Coke	Natural Gas and CBM	Industrial electricity	COMMERCIAL Space heating Air conditioning Lighting
Coal Bed Methane	Heat Plants	Synthesis gas	Commercial space heating	
Uranium	Oil refining	Electricity	Commercial air conditioning	RESIDENTIAL (urban & rural) Lighting Cooking Water & space heating
Biomass	Fuel Cell Power/CHP	Heat	Urban cooking and water heating	
Geothermal	Hydrogen production	Biogas	Urban space heating	AGRICULTURAL Electric motors Processing Irrigation Farming Machines
Hydro	Ethanol production	Hydrogen	Urban air conditioning	
Solar	Gasifier/Digester		Lighting and appliances	TRANSPORT Air Ship Road Rail Pipeline
Wind	Hydro Power		Rural cooking and water heating	
	Solar Power			
	Wind Power		Agricultural processes	

Note: This list of subsectors, sources, carriers and technologies is presented for illustration purposes only. Not all of them are always present in different developing countries, and for the purpose of the I&FF assessment only some of them (or even other subsectors defined at different levels of aggregation) are likely to be selected.

Source: E.D. Larson, P. DeLaquil, Z. Wu, W. Chen, and P. Gao (2002): Exploring implications to 2050 of energy technology options for China. Prepared for the Sixth Greenhouse Gas Control Technologies Conference, Kyoto, Japan, September 30 – October 4, 2002. Available under: http://www.princeton.edu/pei/energy/publications/texts/Larson_Kyoto_-02.pdf.

3.2 Application of I&FF Methodology to Energy Sector Mitigation

This section describes how the I&FF methodology described in Chapter II would be applied to estimate the additional financial needs to implement the key mitigation options in the energy sector. For this reason, and to avoid repetition, some of the information provided in Chapter II that is relevant to all sectors is not included in this chapter. Careful reading of Chapter II before this chapter is highly recommended.

Step #1: Establish key parameters of assessment

>>> Define detailed scope of the sector

In this step, the assessment team will define the precise subsectors that are to be included in the I&FF assessment. This involves selecting the specific processes, activities, entities, and subnational areas or regions to be included in the energy sector for the purpose of the I&FF assessment. It is recommended to include the most important components of the energy supply subsector, as well as the most important end-use subsectors. The selection of the subsectors, and exactly how broadly or narrowly they are defined, should depend on national circumstances, priorities and data availability. National circumstances refer, more specifically, to the structure of each subsector and the relative importance of its components in terms of GHG emissions, opportunities for effective mitigation, contribution to the national economy and potential for economic growth, and their relationship to national and sectoral development plans. This choice should also depend on data availability, and consider the scope of (and subsectors included in) mitigation assessments previously completed, such as the analysis of mitigation options in the context of the National Communications.

Energy supply subsectors may be defined in terms of a specific production process or energy carrier (e.g., electricity generation; coal production) or alternatively by defining a whole production chain linking a specific energy carrier and the related energy source, such as, coal based-electricity.

Similarly, there are numerous ways to define energy end-use subsectors. The simplest definition often applied identifies just three sectors: industry, residential and transport (see, for example, the Fourth Assessment Report of IPCC[15]). Figure 3-1, by contrast, considers five end-use sectors: industrial, commercial, residential (urban & rural), agriculture, and transport, taking into account that further detail on the scope of the subsectors analyzed may be of interest in developing countries. How countries choose to define their end-use sectors should depend upon national circumstances (which include the scope of energy supply subsectors;

---

[15] IPCC (2007). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O.R. Davidson, P.R. Bosch, L.A. Meyer (eds.), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 851pp. Accessible at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

energy supply and demand technologies, and the relative economic importance of different sectors, etc.) and priorities, as well as on data availability and to guarantee compatibility with other sources of data such as National Communications and sectoral studies.

In addition, it should be kept in mind that the aggregation level should be compatible with usual practices of sectoral analysis in the country. For example, if it is customary to conduct sectoral analysis using a specific analytical model (e.g., to make projections, estimates and to calculate investment and operating cost needs) the level of aggregation adopted for I&FF assessment should be compatible with that model and data. Further discussion of energy models that may be useful for the IF&FF assessment is offered in Box 1 at the end of the chapter.

The relevant energy supply and demand side subsectors and GHG emission sources to be considered in the IF&FF assessment would typically be those identified in national GHG inventories as those with highest contribution to total GHG emissions and mitigation potential. The reasons for their selection, as well as their relevance and mitigation potential are all key issues that will be discussed in the introduction and conclusions of the report. Other relevant criteria to select subsectors and technologies to consider will typically include cost effectiveness (e.g., US dollars per GHG ton reduced) and absolute costs.

Important direct linkages between the energy sector, as defined for the I&FF assessment, and other sectors should be noted. For example, the energy sector receives important inputs from the agriculture and forestry, waste management and water management sectors. The agriculture and forestry sectors are key raw material suppliers for biofuel production. The waste management sector is a source of energy through waste incineration and the collection and use of landfill methane. The water management sector provides inputs for hydropower generation and for cooling in electricity and heat production. Care should be taken to avoid double-counting of I&FF due to sectoral overlaps (e.g., substitution of energy intensive materials with woody biomass could be included in energy mitigation or forestry mitigation), and inconsistent results (e.g., if hydropower development is a mitigation option for the energy sector, adaptation measures in the water sector should not assume pre-hydropower development conditions). Whenever such overlaps may arise due to the choice of mitigation and adaptation sectors included in the country's I&FF assessment, a specific subsection should indicate how double counted will be avoided (e.g., by stating the processes and/or options to be included in each sector).

>>> Specify assessment period and base year

This methodology recommends a 25-year assessment period and 2005 as the base year. If another year must be used for the base year due to data limitations or other national circumstances (e.g., 2005 being a bad or untypical year), the assessment period should still be 25 years in length. This recommendation is based on the need to take into account the long lifetimes of energy infrastructure. Therefore, if 2007 is chosen as base year, the recommended end period should be 3032. In any case, the reasons for selecting a given base year and time horizon as well as the circumstances and hypotheses underlying the IF &FF estimates regarding ongoing investment plans should be documented in the report. This may be key to understand the results of the assessment. For example, if there is an ongoing 10 year electricity infrastructure investment plan, the assessment team may choose to make clear that IF will be the same under the baseline and mitigation scenarios for a given time period. This seems a good choice if the investment plan is just one element among many defining IF for the sector. Alternatively, if this hypothetical plan is the key element defining IF for the sector, the team may choose instead to change the base year in order to reduce as much as possible this overlap between baseline and mitigation scenarios.

>>> Identify preliminary mitigation options

A preliminary set of mitigation options must be identified for each relevant energy supply and each energy end-use subsector selected for the assessment. Table 3-1 presents a list of general mitigation options by subsector. The IPCC Working Group III Report of the Fourth Assessment Report,[16] and the references contained therein, provide more detailed descriptions of mitigation measures for the energy supply and energy end-use sub-sectors.

The selection of options should be based on the sectoral scope, the country priorities for the sector, previous results from analyses of mitigation priorities (e.g., from National Communications), the consistency with national and sectoral development plans and goals, current and expected future energy supply and demand characteristics. The later relate to fuel sources, demand subsectors undergoing greatest growth, etc.

Other criteria that a country may consider to prioritize mitigation options include:
- Capital and operation costs
- Cost effectiveness (cost per ton of GHG abated)
- GHG mitigation potential
- Environmental and social co-benefits
- Economic co-benefits at the macro and micro levels (balance of payment and growth impacts, development impacts, job creation, etc.)

[16] IPCC (2007). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O.R. Davidson, P.R. Bosch, L.A. Meyer (eds.), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 851pp. Accessible at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

Table 3-1: Energy sector mitigation measures

Primary Subsector	Secondary Subsector	Mitigation Measures	
		Improve Efficiency of Energy Use	Reduce Emissions per Unit of Energy
Energy Supply	Electricity and Heat Generation (power plants, CHP plants, heat plants)	Plant efficiency improvements (upgrade existing plants, build new higher efficiency plants)	Switch to lower carbon fossil fuels (e.g., coal to gas) Switch to renewable sources (solar, wind, tidal, hydro)
	Electricity Transmission and Distribution, and Heat Distribution		Reduce transmission and distribution losses of electricity Reduce distribution losses of steam Reduce SF_6 and PFC leakage from electrical transmission and distribution equipment
	Oil and Natural Gas Industry	Efficiency improvements at oil refineries, and natural gas processing facilities	Reduce fugitive emissions from oil and gas production by flaring CH_4 rather than venting, and/or collection and utilization rather than venting and flaring Reduce fugitive emissions of CH_4 from natural gas transportation and distribution systems
	Coal Industry	Efficiency improvements at coal processing facilities	Reduce fugitive emissions from coal mining by CH_4 collection and utilization
	Biofuels (e.g., production of charcoal, ethanol, biodiesel and peat; anaerobic digestion of organic wastes)	Efficiency improvements in charcoal manufacture and ethanol production	Reduce CH_4 leakage from anaerobic digesters
Energy Demand	Industrial Production	Use of efficient end-use electrical equipment Heat and power recovery	
	Transport: Road Traffic	Higher efficiency vehicles, including hybrids, cleaner diesel vehicles, and improved structural design vehicles Improved maintenance of vehicles Modal shifts from road to rail and public transport systems, and to non-motorized transport (cycling and walking) Land-use and transport planning	Utilize biofuels
	Agriculture	Higher efficiency motors and vehicles	Use of renewable energy for pumping water/irrigation.
	Buildings (Commercial, Institutional, and Residential)	Efficient lighting and daylighting More efficient electrical and gas appliances, and heating and cooling devices Improved cookstoves Improved insulation and air sealing Improved building design and siting	Switch to renewables for space heating/cooling and for water heating (passive and active solar, geothermal), designing aspects, Installation of HVAC (Heating, Ventilation and Air Conditioning) systems.

Source: Elaboration by the authors.

The result of this identification and prioritization exercise would be a short list of mitigation options (e.g., no less than 5 and ideally no more than 10 options for the sake of tractability and in order to keep the policy discussion manageable).

>>> Select analytical approach

Demand and supply projections are a basic input for the elaboration of scenarios and the subsequent analysis of I&FF related to mitigation in the energy sector. These may be readily available from existing national development or energy plans (that further detail how these demand projections are estimated and will be met by supply) or National Communications. However, in some cases they may need to be elaborated – e.g., to extend existing projections – for the specific timeframe of the I&FF assessment. This will necessarily call for an analytical approach.

The analytical approaches recommended for the assessment of I&FF associated with energy mitigation options range from simple spreadsheet models that can be built by members of the project team to well-established energy models already in use in the country. It is important to stress that given the project constraints in terms of both time and resources, it will not be possible to build additional analytical capacities for this assessment, e.g., to incorporate and estimate new models. For this reason, the use of sophisticated energy or energy-economy models is only recommended whenever these are already known and customarily used locally for sector analysis (e.g., by energy experts or in the context of the elaboration of National Communications). A combination of approaches, e.g., an energy-economic model supplemented with spreadsheet analysis, eventually with the help of costing tools, could also prove suitable.

Many energy models and costing tools have been widely used in developing countries in the context of national and global energy-sector mitigation assessments[17]. These could also be used for an I&FF assessment. The models are often referred to as either "top-down" or "bottom-up" models, depending upon how they treat energy fuels, technologies, and

[17] An illustrative list of models and tools applied for the analysis of investment and costs in the energy sector would include:

ENPEP (the ENergy and Power Evaluation Program), developed by Argonne National Laboratory (ANL) and the International Atomic Energy Agency (IAEA);

MARKAL (Market Allocation), developed in a collaborative effort under the auspices of the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA);

LEAP (the Long-Range Energy Alternatives Planning System) developed by the Stockholm Environment Institute;

MESSAGE (Model of Energy Supply Strategy Alternatives and their General Environmental Impacts), developed by IIASA (International Institute for Applied System Analysis);

WASP (Wien Automatic System Planning Package), developed by the International Atomic Energy Agency (IAEA);

MAED (Model for Analysis of Energy Demand) developed at IAEA;

RETScreen, developed by Natural Resources Canada to evaluate various types of renewable-energy and energy-efficient technologies (RETs);

HOMER, developed by the National Renewable Energy Laboratory (NREL);

CO_2DB, database containing detailed data on carbon mitigation technologies, developed by IIASA;

Energy Costing Tool, developed by UNDP and the UN Millennium Project.

markets, and the rest of the economy[18]. Hybrid approaches, which utilize both "top-down" approaches and "bottom-up" approaches, are also used. Information from bottom-up studies, if available from previous assessments or sectoral analyses, is recommended for I&FF assessments due to their dissagregate approach and their emphasis on energy fuels, technologies, and markets rather than the behaviour of the entire economy, as well as their greater transparency compared to top-down models.

If an energy model is not suitable, a sectoral plan or a projection of trends can be used as the basis for the analysis. Energy ministries, regulatory agencies, or electric utilities may have expansion or development plans for some part (e.g., electricity supply) or all of the energy supply system. These plans would be based on projections of energy demand in relevant end-use sectors.

Step #2: Compile Historical IF, FF, and O&M Cost Data, Subsidy Cost Data (if included explicitly), and Other Input Data for Scenarios

In order to help and validate the construction of baseline and mitigation scenarios and calculate the associated I&FF and O&M flows, the availability of a set of historic data on these variables may prove key. Since investments may not occur every year and these flows as well as operating costs may be spread over long periods, the I&FF methodology recommends that countries compile 10 years of historical I&FF data, i.e., for the base year and the previous nine years in order to have a "sample decade" of how these flows were spread and the magnitudes involved. At a minimum, countries should collect at least three years of data (i.e., for the base year and two years during the previous decade).

>>> Compile historical annual IF and FF data, disaggregated by investment entity and source

Data should be compiled for each investment type (i.e., relevant technologies involved in current conditions and under mitigation options, e.g., thermal power plants, renewable power plants, etc.) and financial flows (i.e., All expenditures not involving durable goods, such as expenditures associated to information campaigns or other public programmes, or industry programmes, e.g., on Research and Development and Demonstration -R&D and D-). Data should be annual, disaggregated by investment entity, and, if possible, by funding source, and also be divided into investment flows and financial flows (see Table 2-3 in Chapter II).

The definitions of investment types, especially how narrow they are (e.g., combined cycle thermal power plant or simply power plant differentiated by fuel), will depend on the national circumstances, in particular, to the relevance of specific technologies and mitigation options in the country, the sectoral scope chosen and the level of detail of the analytical approach.

---

[18] See, for example: UNFCCC (2008). UNFCCC Resource Guide for Preparing the National Communications of Non-Annex I Parties, Module 4 Measures to Mitigate Climate Change, Bonn, Germany, 32 pp. Accessible at: http://unfccc.int/essential_background/background_publications_htmlpdf/items/2625.php

The I&FF data needed may reside in one or more of several locations (e.g., national accounts, national planning bodies or commissions and ministry records and plans, industry records, statistical agencies, utilities, research institutions). Note that sectoral and subsectoral definitions and disaggregations will vary among data sources, so assumptions may need to be made to reconcile datasets and extract needed data from aggregated categories. For example, the UN System of National Accounts utilizes the International Standard Industrial Classification (ISIC) classification system in which energy supply activities are dispersed among four separate sections (the highest, or most aggregated, classification level).[19] Also, even at the most disaggregated level in the ISIC system, multiple energy activities are combined so that investment information for each activity cannot be separated without making some assumptions and/or using supplementary information.

It is recommended that local sources of sectoral data (energy and industry ministries, industry associations and NGOs) providing the most dissagregate level of information or National Communications data be chosen instead of (aggregate) national accounts sources.

>>> Compile historical annual O&M cost data, disaggregated by investment entity and source

Historical O&M data are also needed to provide a historical basis from which to estimate future O&M costs for new physical assets, as well as to provide data for the first year of the scenarios. Annual O&M costs for the physical assets that are in operation during the historical period should be collected (or estimated) for the same years for which historical I&FF data are collected. Information about the expected lifetimes of the assets in operation during the historical period, and annual fluctuations in O&M costs (if any), also need to be collected. O&M data should be collected at a level of disaggregation consistent with the I&FF data, and the O&M data for assets purchased *during* the historical period should be tracked separately from the O&M data for assets purchased *before* the historical period (see Table 2-4 in Chapter II).

The O&M data may reside in one or more of the locations for I&FF data (e.g., national accounts, ministry records and plans, industry records, statistical and regulatory agencies, utilities, research institutions). If such data are not available, countries should utilize one of the estimation approaches described in Chapter II (extrapolation, utilization of international sources and costing models, etc.).

>>> Compile historical annual subsidy cost data, if subsidies are included explicitly in the assessment

There are numerous types of energy subsidies, including direct financial transfers (e.g., grants and low-interest loans to producers), preferential tax treatments, trade restrictions, direct investment in energy infrastructure, demand guarantees and mandated deployment rates, price controls, market-access restrictions, and controls over access to resources. If a country chooses to include subsidies explicitly in the I&FF assessment, annual costs of

[19] ISIC (the International Standard Industrial Classification of All Economic Activities) is a UN system for classifying economic data. The latest version (ISIC Rev.4) is accessible at: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27

subsidies for each type of investment during the historical period should be collected (or estimated) for the same years for which historical I&FF data are collected. Subsidies should be compiled separately for IF, FF, and O&M (see Table 2-5 in Chapter II).

Information on subsidies may be available from relevant government ministries or agencies, statistical agencies, research organizations, academic institutions, and private sector entities.

>>> Compile other input data for scenarios

In addition to historical I&FF and O&M cost data, the characterization of the scenarios and estimation of annual costs for the scenarios will require the collection of other historical, current and projected or estimated data relevant to the sector.

Firstly, it will be important for the energy experts included in the team to provide general information on major sector and macroeconomic policies (both recent and expected) that have an incidence on energy supply and demand projections and energy costs.

Secondly, more data will be needed in order to match the analytical approach chosen (e.g., to project supply and demand for different sub-sectors), the sector scope, and modelling needs if a model is used. It is very likely that additional data will be needed, such as those indicated in the following listings.

If the primary energy subsector is included:

- Data to characterize primary energy supply, such as: contribution of fossil fuels/nuclear/renewables to total primary energy; details on fossil fuel domestic production, imports, and exports; projections for primary sources over the assessment period, and especially for renewables, an assessment of potential for growth in supply.

If the electricity generation/distribution subsector/s are included:

- Inventory of and characterization of heat and power generation facilities. This includes: the type of fuel/energy source; technology type (e.g., combined cycle); operating costs; performance characteristics (e.g., fuel requirements, efficiencies); time schedule of retirement (or expected lifetime for each investment type considered); planned capacity additions (e.g., under national energy or development plans) and upgrades over the assessment period.
- Inventory and characterization of energy transformation facilities
- Inventory and characterization of electricity and heat transmission/distribution infrastructure
- Characterization of alternative higher efficiency and/or lower carbon heat and power generation technologies, including information about operating costs and performance characteristics
- Characterization of other energy supply mitigation measures (e.g., measures to reduce transmission and distribution losses of electricity), including information about operating costs and performance characteristics

If the energy end-use subsectors are included:

- Characterization of energy end-use demand by fuel/energy carrier type and by end-use sector, including information on drivers of growth (e.g., demographic change and urban development), domestic demand forecasts, and for those countries that have significant export industries for fossil fuels, refined products, or electricity, demand forecasts in neighbouring countries or international markets
- Characterization of alternative higher efficiency and/or lower carbon end-use technologies (e.g., high efficiency passenger vehicles, high efficiency industrial motors, passive and active solar water heaters, high efficiency cook stoves), and of higher efficiency end-use infrastructure (e.g., public transport, improved building design) including information about operating costs and performance characteristics

Step #3: Define Baseline Scenario

This step entails characterizing each selected energy supply and/or energy end-use subsector over the assessment period assuming that no new policies to address climate change are implemented. It should reflect current macroeconomic conditions, sectoral and national plans and their ongoing implementation, expected socioeconomic trends, and expected investments in the subsectors. The baseline scenario may be based on a model, a sectoral plan, a projection of trends, or some combination including projections and actual I&FF (e.g., between 2005 and 2008), if available. In addition to specific information about how both energy supply and demand are expected to evolve over the assessment period, the baseline scenario description should include specific information about facility and infrastructure investments that are expected in each subsector (e.g., the timing and magnitude of capacity additions in the power sector, for each investment type selected), as well as programmatic investments (e.g., the timing, nature, and magnitude of an energy R&D and public or private or mixed program).

Step #4: Estimate Annual IF, FF, and O&M Costs, and Subsidy Costs if included explicitly, for Baseline Scenario

>>> Estimate annual IF and FF for each investment type, disaggregated by investment entity and funding source

In this step, annual facility and infrastructure IF for the baseline scenario and annual FF (programmatic flows) for the baseline scenario are estimated for each subsector. IF should be detailed per investment type (e.g., purchase or incremental investment in a given type of equipment) or FF type (e.g., given type of programmatic expenditure, such as costs of a R&D and demonstration programme). As discussed in Chapter II, I&FF should be measured in real terms (i.e., deflated and presented in constant 2005 US$[20]), reported in the year in which they are expected to be incurred, and for cumulative calculations, they should be

[20] Deflated values of a variable (such as annual IF data) are typically calculated by correcting the nominal value of the variable in a given period t (e.g. ift). To do this the nominal value ift is multiplied by the relevant base year price index (e.g. P2005) and it is divided by the price index of the corresponding year (i.e. Pt). For example, real IF for year t is given by IF_t = $if_t \cdot \left(\frac{P_{2005}}{P_t}\right)$. The relevant price index is the one customarily used for deflating energy sector data (e.g. service or utilities price index, wholesale, etc.)

discounted using appropriate public and private discount rates. Furthermore, annual IF (purchase and improvement of durable goods) and FF (all expenditure that is neither investment nor operation and maintenance costs, such as programmatic expenditures) data should be disaggregated by investment entity and funding source. Data would be obtained either through the use of models or other projection tools, and/or government and private sector planning documents, or estimates might be derived from historical data.

The output of this step will be a stream of annual investment flows and/or financial flows for each investment or FF type (defined generically in terms of technology/fuel, type of programme, etc.) and subsector for the entire assessment period. Output will also include data on the investment entities involved (e.g., private sector utilities at aggregate level or public sector) and funding source. These data should be organized as in Table 2-3 presented in Chapter II.

>>> Estimate annual O&M costs for each IF, disaggregated by investment entity and funding source

Annual estimates of O&M costs for assets (investment types) purchased during the assessment period, and for assets purchased before the assessment period and that are expected to still be in operation, need to be collected (or derived) for each selected subsector. Costs should be reported in real terms, ideally in constant 2005 US$, should be reported in the year in which they are expected to be incurred, and should be discounted. The annual O&M estimates for each investment type should be disaggregated by investment entity and funding source (as in Table 2-4 in Chapter II), and also be divided into O&M for assets purchased during the assessment period, and for assets purchased prior to the assessment period. For those assets purchased during the assessment period that are expected to still be in operation after the last year of the assessment period, annual O&M costs for each additional year the assets will be in operation should be estimated, up to an additional five years after end of the assessment period. Possible data sources include those described above for IF and FF, notably local sources (sectoral plans and projections, national communications, and eventually national accounts) and international sources (costing data and tools).

>>> Estimate annual subsidy costs for each investment type and for IF, FF, and O&M costs, if subsidies are included explicitly in the assessment

If a country chooses to include subsidies explicitly in the I&FF assessment, annual subsidy costs should be estimated for each relevant investment type, and for all categories of cost (IF, FF, and O&M), in the baseline scenario (see section 2.2.1 of Chapter II).

Step #5: Define Mitigation Scenario

This step entails developing a description of what is likely to occur in each selected energy supply and energy end-use subsector, over the assessment period, if mitigation efforts are implemented to address climate change. This would include comprehensive descriptions of the specific mitigation measures that would be implemented (technology types, implementing subsectors, etc.), and the implications of those measures for the evolution of the subsectors (e.g., a reduction in capacity needed in the power sector due to electricity savings in the industry and the buildings sector). The mitigation measures need to be defined clearly and completely so that IF, FF, and O&M costs can be estimated in the next step. This should include specific information about facility and infrastructure investments that would occur in each subsector (e.g., the timing and magnitude of facility upgrades and capacity additions in the power sector, by technology type; the timing, number, and characteristics of more efficient end-use equipment, etc.), as well as programmatic investments (e.g., the timing, nature, and magnitude of a renewables research and development program). A model, an adjusted sectoral plan, a projection of trends, or a combination can be used as the basis of the projection. Prior work on climate change (e.g., National Communications, Technology Needs Assessments, GHG mitigation assessments) should be utilized in this step.

In determining and defining the set of mitigation measures that would be implemented, the preliminary set of the mitigation measures that were identified in step #1 should be re-evaluated, given the analytical approach chosen in step #1, the other input data compiled in step #2, and the baseline analysis completed in step #3. The team would also count on the previous prioritization of mitigation options from step #1, which will be re-evaluated later in step #8.

As part of the re-evaluation and initial prioritization of mitigation measures, countries should assess qualitatively the GHG and non-GHG benefits, as well as potential non-investment costs (negative externalities), of the mitigation measures.

Non-GHG benefits to consider could include:

- Sales revenues: Investments in energy supply facilities, and in end-use facilities and infrastructure that produce goods or services (e.g., public transport systems), will accrue sales revenues, which can significantly (or more than) offset investment and operating costs.
- Energy security: Mitigation measures that enhance domestic energy supplies (e.g., development of renewable energy technologies) can increase national energy security.
- Reduced air pollutants: Switching to lower carbon-content fossil fuels, or to renewables or nuclear energy, and utilizing fossil energy more efficiently, can significantly reduce air pollutants, with consequent benefits to both human and ecological health.

Negative externalities could include:

- Damages from hydropower development: Hydropower projects can disrupt ecosystems upstream and downstream from facilities, and the filling of reservoirs can displace settlements.
- Increased competition for resources: Increasing agricultural and woody biofuel supply can increase demand for productive lands, and exacerbate existing land availability constraints. Thermal electricity and heat generation plants (which require significant quantities of water for cooling) and hydroelectric facilities can reduce water supply.
- Emissions leakage: Switching to a lower carbon fossil fuel (e.g., coal to gas) for combustion may inadvertently result in higher fugitive emissions depending on fuel

characteristics, and fuel production and transport operations. Hydropower reservoirs can result in additional CH_4 emissions due to anaerobic decomposition of organic material in floodwaters.

It is quite important that the single criterion or the group of criteria used to select the pecking order of priority measures be clearly explained or specified (e.g., through a text box or simple multi-criteria analysis table where each measure is given a grading normalized to a range 0-10). It is also recommended to present the results from these qualitative assessments in a specific section in the sectoral I&FF report.

Step #6: Estimate Annual IF, FF, and O&M Costs, and Subsidy Costs if included explicitly, for Mitigation Scenario

>>> Estimate annual IF and FF for each investment type, disaggregated by investment entity and funding source

In this step, annual IF for the mitigation scenario facility and infrastructure investments, and annual FF for the mitigation scenario programmatic investments, are estimated for each subsector. As discussed in Chapter II, costs should be in real terms (i.e., inflation adjusted), ideally in constant 2005 US$, should be reported in the year in which they are expected to be incurred, and should be discounted using appropriate public and private discount rates. The annual IF and FF estimates for each investment type should be disaggregated by investment entity and funding source, and also be divided into investment flows and financial flows. Data sources could include model output, and/or government and private sector planning documents, or estimates might be derived from historical data.

The output of this step will be a stream of annual investment flows and/or financial flows for each investment type in each subsector for the entire assessment period, by investment entity and funding source. These data should be organized as in Table 2-3 in Chapter II.

>>> Estimate annual O&M costs for each IF, disaggregated by investment entity and funding source

Annual estimates of O&M costs for assets purchased during the assessment period, and for assets purchased before the assessment period and that are expected to still be in operation, need to be collected (or derived) for each subsector. Costs should be in real terms, ideally in constant 2005 US$, should be reported in the year in which they are expected to be incurred, and should be discounted. The annual O&M estimates for each investment type should be disaggregated by investment entity and funding source (as in Table 2-4 in Chapter II), and also be divided into O&M for assets purchased during the assessment period, and for assets purchased prior to the assessment period. For those assets purchased during the assessment period that are expected to still be in operation after the last year of the assessment period, annual O&M costs for each additional year the assets will be in operation should be estimated, up to an additional five years after the last year of the assessment period. Possible data sources include those described above for IF and FF.

>>> Estimate annual subsidy costs for each relevant investment type and for IF, FF, and O&M costs, if subsidies are included explicitly in the assessment

If a country chooses to include subsidies explicitly in the I&FF assessment, annual subsidy costs should be estimated for each relevant investment type, and for all categories of cost (IF, FF, and O&M), in the baseline scenario (see section 2.2.1 of Chapter II).

Step #7: Calculate the Changes in IF, FF, and O&M Costs, and in Subsidy Costs if included explicitly, needed to Implement Mitigation

The changes in IF, FF, and O&M costs that are needed to implement the mitigation measures in each subsector are calculated in this step by subtracting baseline scenario costs from mitigation scenario costs. There are two primary objectives of this step: 1) to determine how cumulative IF, FF, and O&M costs would change; and 2) to determine how annual IF, FF, and O&M costs would change. These calculations, which should be completed for each subsector, are described in detail in Chapter II.

Step #8: Evaluate Policy Implications

The purpose of this step is to evaluate the policy implications of the assessment results for the sector. The analyses in the previous step provide an estimate of the magnitudes and timing of changes in IF, FF, and O&M by each investment entity and from each funding source that would be needed to implement the mitigation measures in each subsector. These results should be supplemented by information with regard to the implementation and financial feasibility of the mitigation scenario delineated and the policies that may help in this direction.

>>> Re-evaluate priority mitigation measures

It is recommended that countries first re-evaluate their initial prioritization of the mitigation measures (undertaken in step #5), based upon the incremental cost estimates and discuss a final list of priority measures in terms of the main criteria, such as: incremental cost, GHG mitigation potential; cost effectiveness; and co-benefits).

>>> Analyze feasibility and compatibility with development and sector plans

Subsequently the results should be used to identify which type of investment entities (e.g., public utilities, private firms or state agencies at this aggregate level) are responsible for the most significant (largest and/or highest priority) changes in I&FF (i.e., Incremental I&FF), as well as the predominant sources and potential limitations of their funds.

The feasibility of meeting these additional financial needs and the compatibility between the implementation of priority measures and national development and sector plans should also be discussed, e.g., in view of ongoing policies and measures.

>>> Analyze policy implications

Finally, in view of all of the above, the policy measures that might be used to induce those entities to implement the proposed measures and change their investment patterns should be discussed, as well as the additional sources of funds that might be utilized to meet new investment needs. It will be particularly important to distinguish between public and private as well as between domestic and foreign sources of additional finance.

Policy measures include a variety of instruments, including economic instruments (e.g., taxes), regulatory instruments (e.g., fuel portfolio standards), voluntary agreements, information dissemination and other instruments (e.g., research, development, and demonstration (RD&D) programmes) (see Table 3-2 below). The suitability and acceptability of different instruments or policy initiatives to advance the implementation of the priority mitigation measures should also be briefly discussed.

Table 3-2: Potential policy options to encourage GHG mitigation in the energy sector

Policy options / Policy objectives	Economic instruments	Regulatory instruments	Policy processes: Voluntary agreements	Policy processes: Dissemination of information and strategic planning	Policy processes: Technological RD&D and deployment
Energy efficiency	• Higher energy taxes • Lower energy subsidies • Power plant GHG taxes • Fiscal incentives • Tradable emissions permits	• Power plant minimum efficient standards • Best available technologies prescriptions	• Voluntary commitments to improve power plant efficiency	• Information and education campaigns.	• Cleaner power generation from fossil fuels
Energy source switching	• GHG taxes • Tradable emissions permits • Fiscal incentives	• Power plant fuel portfolio standards	• Voluntary commitments to fuel portfolio changes	• Information and education campaigns.	• Increased power generation from renewable, nuclear, and hydrogen as an energy carrier
Renewable energy	• Capital grants • Feed-in tariffs • Quota obligation and permit trading • GHG taxes • radable emissions permits	• Targets • Supportive transmission tariffs and transmission access	• Voluntary agreements to install renewable energy capacity	• Information and education campaigns • Green electricity validation	• Increased power generation from renewable energy sources
Carbon capture and storage	• GHG taxes • Tradable emissions permits	• Emissions restrictions for major point source emitters	• Voluntary agreements to develop and deploy CCS	• Information campaigns	• Chemical and biological sequestration • Sequestration in underground geological formations

Source: IPCC (2007). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O.R. Davidson, P.R. Bosch, L.A. Meyer (eds.), Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 851pp. Accessible at: http://www.ipcc.ch/ipccreports/assessments-reports.htm