Handbook

for Estimating the Socio - economic and Environmental Effects of **Disasters**

Economic Commission for Latin America and the Caribbean
ECLAC

Section Three
Infrastructure

Introductory note: Three main infrastructure sectors are included in this section: energy (both the electric power and oil segment), drinking water and sanitation, and transport and communications.

I. ENERGY

A. INTRODUCTION

Energy, like all other sectors, sustains direct damages and indirect losses during and after disasters, and their macroeconomic impact must also be ascertained. Direct damages refer to the immediate damage or destruction of physical infrastructure and inventories available at the time of the disaster. Indirect losses refer to the costs of satisfying demand for energy during the recovery period, as well as the net income or profit that is not received in said period. These indirect losses are used to separately assess the macroeconomic effects.

One must determine the repair or reconstruction costs required to reestablish pre-disaster operating capacity. A decision must be taken as to whether the new operating capacity should be equal to the one in place prior to the disaster or incorporate updated efficiency and security standards. Valuation criteria at current replacement cost –including technological innovations– will provide a more accurate cost of the works to be carried out in practice and the financial resources they will require.

The cost estimate must take into consideration the time needed for repair work to be completed and the costs of meeting temporary needs, as explained below in the section on indirect losses.

It is much easier to estimate stocks of equipment, materials and raw materials that were damaged or destroyed by the disaster, with replacement costs at current market prices. If at the time of the assessment, there are no equal goods available in the market, it is necessary to use the cost of the most similar goods in order to obtain equivalent or approximate results.

The quantification of indirect losses is a more complex task because it is based to a greater degree on estimates. On the one hand, the behavior of supply and demand during the rehabilitation period must be estimated; on the other, the financial results that will actually be obtained over the same period must be compared to those that would have been obtained if the disaster had not occurred. In the projection of what will happen after the disaster, results will clearly be lower than those estimated before the disaster, because large consumers will have reduced their energy demands. Though it is less likely, energy demand could increase if large amounts of energy are required for repair works. Both situations may actually occur concurrently, in which case a quantification of the net results must be made.

Once the analyst has determined post-disaster demand –which can be equal to, smaller than or greater than normal demand– the means to properly meet it must be identified. As a general criterion, assume that demand for energy will be met somehow. Then estimate the required capital and operating costs, based on how long it takes to rehabilitate all facilities. Capital costs essentially refer to the purchase of equipment, while operating costs consist of labor and materials. Personnel costs should include salaries of plant personnel temporarily laid off for any reasons arising out of the disaster.

Finally, indirect losses must be estimated. Begin by estimating the net income that can be obtained during the rehabilitation period. Then subtract the cost of temporary energy supplies in addition to the company's operational costs during the rehabilitation period from estimated income from energy sales in the same period. Keep in mind that net income thus estimated might be negative depending on the post-disaster purchasing capacity of consumers. Second, estimate the net income that would have been obtained had the disaster not occurred by subtracting total cost from gross income, just as was done in the previous example. This information is often available in the records of companies that manage the sector, especially in their respective short- and medium-term planning departments. The amount of total indirect losses can be determined by the algebraic difference –applicable in cases of real negative income– between the two previously estimated net incomes. These indirect losses would already include the additional costs of temporarily meeting demand, as well as the income that will not be received because of the disaster.

The previous estimates of costs stemming from direct and indirect damage should be broken down, on the one hand, into local and foreign currency components so that they may be used for the overall balance-of-payments calculations. On the other hand, distinctions must be made with regard to damage and losses corresponding to the public sector and to private enterprises, with a view to their utilization in subsequent estimates of national accounts for the calculation of macroeconomic effects.

We recommend the following assessment methodology for the electricity and oil sectors.

B. ELECTRICAL SECTOR

1. Direct damage

Direct damages in the electrical sector usually affect the following three major components of the system: electricity generation plants; transmission lines and distribution grids; and power distribution centers.

a) Electricity generation plants

Electrical energy is generated by hydroelectric and geothermal power plants, as well as by conventional thermal power plants driven by steam, diesel and gas turbines. For the purposes of this Handbook and in light of their special characteristics, consideration is given first to civil works required for the generation of the hydroelectric and geothermal energy. Second, we deal with the power generation plants, where the equipment to transform raw energy into electricity is located.

In connection with hydropower generation, water resource development may require a wide range of works such as diversion and storage dams, channels, tunnels, oscillation chambers and pressurized pipelines. Damage to these facilities must be repaired in order to restore the water supply required for electricity generation; failure to do so would result in the power plant becoming non-operational, and the entire electrical system would be affected. The aforementioned facilities are often located some distance from the main communication routes, so access can be difficult, at least during certain times of the year. In these cases, the direct effects should include any additional costs to repair communication routes; this should not be included in the damage quantified for the transportation sector to avoid double accounting.

To assess the cost of rehabilitation and/or reconstruction of the affected facilities, first an estimate must be made of the following units involved: cubic meters of earth to be removed, including specifications of the type of material involved; amounts of concrete that may be required, broken down by type and strength; the length and other characteristics of water conveyance lines; and the main mechanical components and special facilities. Then an estimate of costs should be made based on current unit values for each type of component. Alternatively, depending on the basic information available, a more detailed procedure can be followed that would consider labor needs by specialty, the amounts of raw materials, the time of use of construction equipment and the unit costs for each of these components. In both cases, the type of damage sustained by the facility, access to basic construction materials -earth, sand and gravel- and the availability of both unskilled and specialized labor will have a direct bearing on the estimation of direct costs. In this regard, cost estimates and bidding proposals made by contractors that have had recent experience in the affected area or in regions with similar conditions will be a valuable source of information.

When considering geothermal power generation, resource extraction and management includes deep wells, conveyance pipe systems and specialized equipment for the processing and collecting of steam. Any estimate of damage to the availability of geothermal power falls outside the scope of the present Handbook and will require the assistance of experts and field research. However, the electrical sector specialist might try to make order-of-magnitude estimates based on updated average costs of drilling deep wells in the area under consideration or in other areas having similar geological characteristics. The alternative procedures that have already been described for hydropower plants should be followed to estimate costs for any remaining generation facilities.

The remaining components for electricity generation refer to the power plants themselves, including the building and a wide array of mechanical, electrical and electronic equipment. An analyst should first focus on equipment and machinery that deliver power to the generator; this basically covers equipment to collect hydraulic energy in hydroelectric power plants and equipment that uses heat energy through boilers, pressure tanks and steam and gas turbines. The former are individually designed to match the characteristics of the hydroelectric site, and their replacement must follow a similar procedure. However, their costs can be estimated by updating the original investment using indexes that reflect the trend in international prices of similar equipment. Manufacturers' catalogues and statistics that show the costs of equipment to collect hydraulic energy in hydroelectric power plants by range of water height (meters) and flow (m^3/sec) of the water resource may also be used.

Equipment used for the mechanical processing of energy obtained from steam and from burning oil derivatives is more standardized, although it has specific characteristics depending on the size and type of facility. This includes geothermal as well as conventional power plants classified –depending on the fuel used– as steam-, diesel-, and gas- driven plants.

Their replacement costs can be estimated following the general procedures mentioned above for hydroelectric power plants, which normally are easier to estimate because the equipment is more standardized. Power plants use a range of largely electromechanical equipment to convert raw energy forms –hydraulic, geothermal and those derived from oil derivatives– into electricity. This equipment is generally similar for different types of power plants, but it may vary depending on how up-to-date the plants are and on their specialized functions. The determination of replacement costs first takes into account investments for the original purchase –especially if this was done recently– updated to account for international inflation. A second alternative is to consult cost catalogues published by the manufacturers of this equipment or costs statistics available in specialized publications.

The above comments refer to cases in which installations must be totally replaced. When damage is less severe and only repairs or rehabilitation are required, the cost estimate must be preceded by a technical assessment of the scale of the damage and the real chance of repair. This work will require the participation of specialized personnel having wide experience in the repair and maintenance of this type of equipment. Laboratory tests of the affected equipment will be required to obtain more exact estimates, something that cannot be done in the relatively short time usually available to the disaster assessment team.

The buildings that house all generating equipment must also be assessed. The assessment of their direct damage will follow the same procedures as described for other buildings, as explained below.

b) Transmission and distribution systems

This heading includes transmission, subtransmission and distribution lines and grids, as well as all electrical substations that may be directly related to transporting the electrical power from the generation plants to final consumers.

High-voltage lines that use large and expensive pylons should be assessed first. To do this, field surveys will be required, making use of fast means of transportation such as automobiles when the lines are near to passable routes and light aircraft or helicopters in the case of cross-country lines. It is necessary to estimate the number of damaged pylons, the different types of pylon, and the length of affected electrical cables. In the case of lines that use uniformly distributed posts, only the number of kilometers of affected lines will be needed, with an indication of whether the damage is limited to the pylons or whether it also includes considerable lengths of cables. In addition, transformers and other equipment located along affected distribution lines must also be determined.

Thereafter, a list should be made of affected electrical substations, using the most precise indications possible of all equipment that has sustained any damage, including open-air facilities and equipment located in the main substations.

Estimates of the corresponding costs should be made on the basis of the results obtained from the inspection of the facilities described above. These should take into account all information available on affected power companies or those in neighboring areas. Because these data are frequently used, they should be readily obtainable. As in the case for electrical generation facilities, overall or broken-down costs could also be used, such as data from local or international contractors with experience applicable to the affected area, lists of equipment costs and catalogues.

The above comments on estimating damage in partially affected installations, in contrast to those that must be totally replaced, are also applicable to power transmission and distribution facilities.

c) Energy distribution centers and other works

Electricity measurement and dispatch centers and buildings for administrative offices are also of relevance in the electrical sector. The former are buildings that house a whole range of equipment to monitor and control electricity flows between power generation plants and the main consumption areas. These facilities may range from the most elemental, using manual controls, to the most sophisticated, employing modern remote-measuring and electronic computing systems with a high degree of automated and optimized basic functions. When total reconstruction of these facilities is required, cost estimates should be based on the comprehensive estimates of the energy distribution enterprise. An inventory of the respective parts and an estimate of the extent and magnitude of the damage are necessary in the case of partially damaged equipment and structures; experts should be engaged when specialized equipment is involved.

Damage to administrative buildings and other facilities that might be affected by a disaster can be assessed relatively easily because the characteristics of such structures and constructions are well known. Average prices by unit of floor area or total horizontal space should be ascertained. For a more accurate estimate, unit prices should be estimated for the main elements that comprise such buildings, such as panels, walls, ceilings, window frames and so on.

2. Indirect losses

As previously noted, indirect losses include the additional cost of meeting interim energy demands during the rehabilitation period when affected installations are under repair; they also include net income or profits not received by the power companies during the same period.

a) Temporary supply of electricity

The calculation of the additional cost involved in the temporary supply of electricity will first require an estimate of the time required to rehabilitate the damaged infrastructure. The length of this period will essentially depend on the extent and magnitude of the disaster, and it must be determined on the basis of the assessment of direct damages. Next, it is necessary to estimate electrical demand during the rehabilitation period.

This involves determining the effect that the disaster had on the power company's main customers (generally consisting of industry, commerce and the residential sector). Residential demand projections should contemplate the number of unaffected dwellings; projections of industrial demand should reflect the number of facilities that are in a position to continue operating (including estimated demand for their products); and commercial demand estimates should take into account the operating capacity of the establishments in the affected area. Assumptions must be made for all sectors as to the purchasing power of customers in the period after the disaster to anticipate that potential source of demand constraints. These factors should make it possible to calculate the magnitude and characteristics of the total demand for power.

The electricity sector specialist should then examine alternative ways of supplying the estimated temporary demand. As was said above, this will generally be lower than if the disaster had not occurred, although some customers may tend to increase their use. This review should also contemplate possible solutions for ensuring a rapid re-establishment of electrical service.

In the case of systems in remote locations, all-in-one equipment solutions that can be mobilized and installed quickly in the main load centers should be considered. Their cost can be obtained relatively easily from specialized catalogues or based on recent purchases of such equipment for special needs, such as backup generators for industrial centers or for isolated populations not connected to the national power grid.

Operating costs can be estimated on the basis of specific fuel consumption requirements and the cost of delivery to the area that may be chosen for the temporary generators, which should preferably be located as close as possible to the centers of demand. Estimates of operational costs should be completed by adding labor and materials expenditures, which are normally obtainable from the cost accounting maintained by power companies for the operation of equal or similar equipment.

In the case of damaged systems that are not connected to the national power grid and that are located close to neighboring undamaged systems, the cost of temporarily providing electricity can be estimated quite easily. First, a determination must be made as to whether the undamaged neighboring systems have the capacity to provide the additional power and energy requirements. The cost of interconnection must then be calculated, including the cost of items such as lengths of transmission line, substation equipment and so forth. The rates at which the required power could be provided should be estimated next. If there are no existing agreements established for such emergencies, a reasonable rate based on the additional operating costs to be faced by the system chosen to temporarily provide the power supply should be estimated. In other cases, neighboring systems might be capable of supplying only part of the demand. In this case, the procedures indicated above for isolated and stand-alone systems should be used, in proportion to each one's contribution. Note that because the intention is to establish the additional costs of the provisional service, any reduction in operating costs compared to those the company incurs under normal conditions (such as the variable expenses of generating units that cease to operate because of the disaster) must be deducted from the aforementioned estimates for all alternatives considered.

b) Other indirect losses

Profits not received by the electrical utility during the rehabilitation period (after which demand would tend to normalize) are also indirect losses. It may be assumed that during this period the post-disaster reduction in income will limit the payment abilities of many consumers who need energy to speed up the recovery of their activities; such considerations can be reflected in a provisionally lower rate. It is possible to use such a provisional rate to estimate the gross income and real demand discussed in the previous section. Total costs during the interim period, including additional charges implied by interim service and the company's costs under normal conditions, should be deducted from the gross income thus calculated. This will yield an estimate of the net income during the period in question, which could be negative if there is an increase in expenses along with a reduction in income.

Net income should then be estimated as though the disaster had not occurred. On the one hand, expected income should be considered by applying estimated average income to the normal projection of electricity demand. On the other hand, an estimate of anticipated costs based on recent historic behavior, including direct and indirect costs, should be made in order to calculate normal income for the utility. Power utilities usually employ the expected surplus to cover capital investments made to adequately and opportunely meet future demand. Any significant reduction in operational surpluses would entail new loans that will only be granted if the respective company is financially profitable. Estimates for this second scenario are normally available in power utilities, which constantly require updated short- and medium-term planning.

Indirect losses –which in this case would be equal to the profits not made due to the disaster– would be estimated as the algebraic difference between net income calculated for a normal scenario, with no disaster, and net income estimated for the disaster scenario, including any additional costs of supplying power during the rehabilitation period. Note that when net income is negative in the latter scenario, it must be added to the estimated net income for the normal scenario to obtain the total decrease in profits due to the disaster.

3. Imported content and breakdown of costs

The effects of the disaster on the balance of payments and national accounts may be ascertained from separating direct damages and indirect losses into foreign and national - currency spending requirements, on the one hand, and into public and private - sector spending, on the other. As far as direct damages are concerned, foreign-currency spending should include all equipment, materials and specialized labor that must be imported for the rehabilitation of facilities and machinery.

Local spending refers mainly to construction and repair costs, such as surveying work, earth removal, construction of structures and so forth. However, these items may also include significant foreign-currency spending on specialized equipment such as tractors, trucks and cranes that must be imported. The cost accounting records of power companies or those of contractors with recent experience in the region should prove useful for these estimations.

As far as the foreign-currency component of indirect costs is concerned, one should estimate the expense of temporarily meeting electricity demands in function of the equipment and materials that must be imported for such purposes. The costs of importing electricity from other countries should be included, when applicable.

The separation or breakdown of costs into public and private sectors depends on whether the affected power utility is state or private owned. In addition, when the government provides power services, participation by private companies in related activities, normally in reconstruction or repair contracts for the affected installations, must be taken into consideration.

C. OIL SECTOR

1. Direct damages

a) Production facilities

Oil production involves the drilling of deep wells on land or at sea and the extraction of crude oil. Oil transportation and storage, either for domestic refinement or for export to external markets, fall within the transport sector and should be estimated therewith.

Structures, equipment and facilities that are tailor-made to the needs and characteristics of the geographic environment are used to drill and operate the production wells. They include control rigs, deep drilling rigs, offshore platforms and a wide array of pipelines and equipment to handle the resulting flows of oil. When access to the underground oil deposits has been hampered by a disaster, estimation of damages requires that highly specialized personnel carry out field research.

Such activities are beyond the scope of this Handbook, which refers to estimates that can be carried out in a very short period of time. In the case of total destruction of a given well, the amount of investments already made, updated as of the date of the disaster, would provide a first estimate of direct damage. An approximation of indirect losses would be provided by the net commercial value of production lost during the rehabilitation period. This could then be refined through estimates of damage to such installations as rigs, drilling machinery and auxiliary equipment.

When such facilities have to be replaced because of total destruction, estimates can be made using (updated) standard costs that are normally available in the oil companies' files. Information on costs can also be obtained from manufacturers' catalogues in the case of industrial equipment. Contractors with relevant experience can also be approached. If damaged facilities and equipment can be repaired, it is necessary to assess the magnitude and extent of damage; such estimates require specialized experts with broad experience in repair and maintenance works, preferably familiar with the affected installations.

b) Oil refineries

Refining facilities may be simple when they only cover the stages of primary distillation, but they may be rather complex when they handle more processed products or remove harmful substances such as sulphur. Refineries generally include different kinds of processing towers, storage tanks and a wide array of pipes of differing diameters with various categories of valves and other fittings for managing fluids. Assessing disaster damage at oil refineries should follow the same or similar procedures as those described in the previous chapter for thermal power plants, as they often employ somewhat similar installations.

c) Distribution facilities

The distribution and sale of oil derivatives can be broken down according to the main user sectors as follows: gas for domestic and industrial use; liquid fuels for road, sea and air transport; and bituminous residues that are normally used in road construction. Basic distribution facilities include pipelines, storage tanks, pumping stations (which really belong to the transportation or industrial sectors) and standard service stations that supply fuel to automobiles and small vessels. Damage assessment for service stations involves procedures mentioned earlier in this section.

d) Other facilities

This item includes buildings used for administrative purposes and recreational centers for company personnel. Such facilities are common to all sectors, and their damage assessment requires the techniques described for the housing and human settlements sector.

2. Indirect losses

Indirect losses include the additional cost of providing oil and oil derivatives to meet energy requirements during the rehabilitation of affected facilities. It also includes net income not received during the same period, including the additional costs mentioned above.

a) Temporary supply of oil and oil derivatives

The estimate of costs to temporarily provide oil products must be based on the magnitude and nature of the damage sustained and on the duration of rehabilitation work. These two factors would have already been determined by the time the assessment of direct damage is made. Then the demand for oil and oil derivatives needed to replace lost production capacity and for the reconstruction process should be estimated. This calculation should take into account the extent to which the disaster may affect demand among leading residential, commercial and industrial consumers, all types of functioning automobiles and other vehicles, and roads that have to be constructed or repaired with bituminous material. New demand, in terms of volume and type of oil derivates, should be estimated based on the above factors and with due consideration for the diminished purchasing power of affected consumers.

Once new demand levels are projected, the analyst should consider alternative means for fulfilling that need. Several possibilities may arise, depending on the availability and location of existing resources and the facilities available for transportation and transfer. Tanker trucks should be used to meet small demands near deposits. Active and abandoned pipelines can be used for pumping fuel across greater distances, or new pipelines can be built if their investment can be justified. Finally, tanker ships, such as those commonly used commercially to ship oil and oil derivatives around the world, can be pressed into service using either existing facilities if available or, in their absence, provisional installations adapted to emergency situations.

The corresponding costs should be estimated based on the above considerations and after the most economical and feasible alternative has been selected. In any event, this type of activity falls within the transport and communications sector, and it should be recorded as such. Data on capital and operational costs must be calculated, including the purchase cost of oil and oil-derivatives, which is easily obtained since they are sold at international prices.

b) Other indirect losses

As explained in greater detail in the section on the electrical sector, indirect effects due to lost income can be quantified in the following manner. The net income is determined for the post-disaster scenario. Note that gross income is expected to fall, whereas costs should rise as the greater cost of temporary supply is included. Results will very probably be negative. Then the net income that the company under study would have obtained if the disaster had not occurred is determined. This information can be obtained from the files or forecasts of the oil company itself. In those rare cases when records are not available, estimates can be made based on the files of similar companies. The algebraic difference between net income under normal conditions minus income in the post-disaster situation should yield the total indirect loss, which would be equal to the profit not received by the oil company as a result of the disaster.

3. Breakdown of damages and losses

As in the case of the electrical sector, direct damages and indirect losses are broken down, on the one hand, into domestic and foreign currency for purposes of the balance of payments and on the other, into public and private - sector costs for purposes of national accounts. In the case of the oil sector, the macroeconomic effects might be significant, especially in those cases where the country affected is a net oil and oil derivatives exporter, requiring a much more detailed analysis of the indirect and macroeconomic effects by the energy sector specialist, in close cooperation with the macroeconomics specialist.

4. Effects on employment and on women

The electrical and oil sectors employ a limited number of personnel in view of their relatively high dependency on technology, so these industries tend to have limited repercussions on personal income levels following a disaster. For the very same reasons, no significant differential impact on women is expected to arise from these sectors.

5. Impact on the environment

This setcion describes the main links between assessing damage to the energy - sector and assessing that to the environment. The energy specialist is also referred to the chapter on environmental assessment included in Volume Four of this Handbook.

Some environmental changes related to water resources have a negative impact on hydroelectric power generation. Leaving aside droughts, whose effects are obvious, other disasters –such as floods and landslides– may also affect the availability and quality of water. Landslides can result in the obstruction and diversion of water flows that feed dams, thus affecting resource availability for electrical generation. Floods can increase the silting rates of reservoirs, giving rise to a reduction in their storage capacity and, therefore, in their useful life.

When a watercourse is diverted, river training works are required, and their expenditure should be recorded as indirect damages in the energy sector. A decision to omit such works for technical or financial reasons will compromise the future energy production capacity of the hydropower plant and should be registered as direct damage; this can be estimated as the present value of the difference in net income flows resulting from the disaster. When silting reduces the useful life of a reservoir, the approach is very similar, and damage should be estimated as the present value of the lost net income flow associated with the years of lost production. It must be pointed out, however, that estimation of silt deposition volumes requires lengthy field surveys whose results will not be available at the time of the assessment.

Oil is a non-renewable natural resource that is a part of a country's natural capital. Oil spills of significant proportions are registered as direct damage in the energy sector based on market prices. The environmental assessment seeks to identify the share of these damages that correspond to the contribution of natural capital, isolated from contributions of human capital and other assets such as infrastructure, machinery and equipment. This contribution may be estimated using an economic rent concept that, in the case of underground assets, has methodological difficulties. It will therefore be necessary to use estimates from other sources.[1] To avoid double accounting, these estimates will not be included in the damage overview.

Oil spills and the release of other toxic substances into the environment are another usual effect of disasters. Breakage in oil pipelines is one of the major risks associated with earthquakes. Toxic substances (such as sulphur and other compounds associated with geothermal production) may also be released when their collection and disposal systems are damaged or destroyed.

1 For example, Kunte et al. "Estimating National Wealth: Methodology and Results", Discussion Paper, the Environment Department of the World Bank, Washington, 1998.

In general, these direct damages and indirect effects are accounted for either in the energy or in the transport sector. The environmental specialist should work closely with other members of the assessment team to ensure appropriate damage accounting, especially of the expenses required to restore the environment to pre-disaster conditions.[2] In cases where natural areas are affected by these events, the environmental specialist will most likely be put in charge of calculating those damages. The preferred method for assessing these damages is the restoration cost method described in the chapter on environmental assessment in Volume Four.

An example of how the assessment of the energy sector should be carried out is presented in the following appendix.

APPENDIX VII

DAMAGE TO THE ENERGY SECTOR CAUSED BY THE MARCH 1987 EARTHQUAKE IN ECUADOR

A major disaster occurred in Ecuador in March 1987, caused by a series of earthquakes whose epicenter was located in the northeastern region of the country. The disaster badly affected the living conditions of low-income population groups, destroying their homes and basic services. More serious damage was inflicted on the transport infrastructure used by key sectors of the economy, undermining the country's ability to export and generate foreign currency.

1. Electrical sector

The earthquakes, mudslides and floods caused direct damage to some power plants, national-grid transmission lines and two hydroelectric power plants that were still under construction. They also caused indirect losses because the supply of had to be temporarily suspended in some cities, hydroelectric production had to be replaced with higher-cost energy produced in thermal plants, and the unit operational costs of thermoelectric power plants rose due to an increase in the cost of the transportation of diesel fuel.

The repair of power plants and electricity transmission systems was estimated on the basis of costs provided by the companies that operate them, as were the costs to repair and rebuild the camps at the power plants under construction. Direct total damages were estimated at 3.5 million dollars.

Indirect losses included increased costs in the dams that were under construction, higher electricity production costs because thermoelectric plants were used, and lost revenue at utility companies. Total indirect losses were estimated at 0.3 million dollars.

2 Although the energy specialist may have assessed direct and indirect damages caused by these events, environmental restoration measures may be under the responsibility of institutions not directly related to this sector. In such a case, , it is likely that these expenses would not have been accounted for in the energy sector especially if the solution to the problem depends on the environmental authorities.

Therefore, total damages and losses sustained by the energy sector as a result of the disaster were estimated at 3.8 million dollars. Since most of the equipment and materials to be replaced are not produced domestically, a negative effect on the balance of payments was projected of 2.2 million dollars .

Table 1
SUMMARY OF DAMAGE AND LOSSES CAUSED BY THE EARTHQUAKE IN ECUADOR 1987

Item	Damage, millions of dollars			Effect on the balance of payments[3]
	Total	Direct	Indirec	
Total	3.80	3.51	0.29	2.18
Production infrastructure	0.13	0.13		...
Lines and substations	0.12	0.12		...
Construction work camps	3.26	3.26	--	2.18
Greater generating costs and reduced income from billing	0.29		0.29	--

Source: ECLAC, based on official figures.

2. Oil sector

Although no physical damage was detected in the oil-producing wells, mudflows and floods cut the Trans-Equatorial oil pipeline that links the production area located in Lago Agrio to the refinery and oil and oil derivatives export terminal located in Esmeraldas. The flow of crude from the eastern area, which accounts for 99.6% of national oil production, was interrupted, and approximately 100,000 barrels of oil were spilled. The breaks in the pipeline, of different diameters, covered a total length of approximately 78 kilometers, and civil works at some pumping stations were damaged.

Direct damage to pipelines and related works and the value of the oil spilled was estimated at a cost of 120 million dollars. Reconstruction of the pipeline, following the same route of the previous one to facilitate matters, required a four-month period, and indirect losses were much greater than direct damages (see Table 2).

These indirect losses had domestic and external repercussions on the country's economic performance. They refer to a significant decrease in foreign currency earnings from oil exports throughout the reconstruction period, and to higher costs incurred to meet the domestic demand for oil derivatives.

Domestically, higher costs were incurred to supply liquid gas to the capital city of Quito, owing to the broken pipeline, as alternative routes and means with higher operational costs were used. In addition, the internal demand for oil derivatives had to be met by combining a temporary loan of such products from Venezuela and the building of an alternative pipeline to Colombia in order to extract limited amounts of oil, which were then transported by ship to the Ecuadorian refinery at Esmeraldas.

Oil exports had to be suspended until the pipeline was rebuilt, even though temporary loans from Venezuela and Nigeria made it possible to comply with some foreign commitments. Losses were thus spread over a longer time period than that required for the reconstruction of the pipeline.

3 The value of the components that will have to be imported because they are not produced domestically.

In addition to the above, the Ecuadorian State Oil Corporation (Corporación Estatal Petrolera Ecuatoriana – CEPE) sustained losses due to the reduction in domestic consumption of gasoline, and refineries (private and state) processed a lower volume of oil in their facilities. This loss of profits increased indirect losses caused by the disaster.

In sum, the earthquake caused direct damage to the sector's infrastructure totaling 121.7 million dollars and indirect losses worth 766.7 million, resulting in total damage and losses of 888.4 million dollars. Moreover, the country's balance of payments was affected with a negative impact of around 815 million dollars, caused by the fall in oil exports and the increase in imports required for domestic consumption.

Table 2

DIRECT DAMAGE AND INDIRECT LOSSES CAUSED BY THE I987 EARTHQUAKE IN ECUADOR

Item	Damage, millions of dollars			Effect on the balance of payments
	Total	Direct	Indirect	
Total	888.42	121.67	766.89	815.6
Reconstruction of pipelines, pumping stations, and cost of oil spilled	121.67	121.67	--	66.0
Greated costs for internal supply	90.17	--	90.17	87.3
- Investment in pipeline to Colombia	17.05		17.05	
- Greater transportation costs	15.69		15.69	
- Cost of replacement oil	54.56		54.56	
- Greater liquid gas transportation costs	0.87		0.87	
- Greater transportation costs of derivatives to Oriente	2.00		2.00	
Export losses	662.30		662.30	662.3
- lost exports	64.27	--	64.27	
- chaters of loaned oil	19,60		19,60	
Lost profits	14.28		14.28	
- Reduced consumption	5.27	--	5.27	--
- Reduced processsing in refineries	9.01		9.01	

Source: ECLAC, based on official figures.

The March 1987 earthquake caused 892 million dollars in total damages and losses to Ecuador's energy sector. Of this amount, only 14% are direct damages to the sector's infrastructure, and the remaining 86% are indirect losses. In addition, the disaster had an 818 million dollar negative impact on the balance of payments, mainly due to the inability to meet oil sale commitments abroad. This aggravated the economic situation in the country at the time, which had already been weakened largely as a result of a previous fall in world oil prices.