The Financial Costs of the Chernobyl Nuclear Power Plant Disaster:
A Review of the Literature

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Introduction

Since the discovery of radiation, more than a century ago, its broad uses across society have brought not only benefits but harms (Caufield, 1990). Some of the harms have been to individuals receiving exposures sufficiently high to cause radiation sickness or to increase their risk for cancer and other diseases, and others have affected broad populations placed at risk because of widespread exposures from past nuclear weapons testing, medical uses of radiation, and nuclear accidents. Beyond the dropping of atomic bombs on Hiroshima and Nagasaki, the most dramatic population exposures to radiation have been caused by large-scale nuclear power plant accidents, such as those involving the plants at Three Mile Island, Chernobyl, and Fukushima (Hasegawa et al., 2015). There have been a surprising number of such accidents, although few have reached the scale of those at Chernobyl and Fukushima (Mahaffey, 2014).

Accidents involving nuclear plants, like all disasters, exact costs. There are a variety of mechanisms, both direct and indirect, through which accidents at a nuclear power plant place economic costs on society. While the distinction is not sharp, direct costs refer, for example, to those arising from the damage to the plant and its environs, loss of products, and immediate health consequences (Table 1). The indirect costs are more distal to the accident in their causation and are not a direct consequence of the upset at the plant. Table 1 provides a comprehensive listing of potential sources of costs, dividing them by mechanism, direct or indirect, and by timeframe, short- or long-term. Figure 1 arrays these sources over time since the accident; some damages and attendant costs may be on-going—for example, the

withdrawal of contaminated land and the personal consequences of stigmatization of those who were exposed to radiation and even their children.

Figure 2, adapted from the United Nations Development Programme's (UNDP) 2002 report, *The Human Consequences of the Chernobyl Nuclear Accident. A Strategy for Recovery*, addresses general pathways by which a nuclear power plant accident could cause economic costs (UNDP, UNICEF, UN-OCHA, & WHO, 2002). The figure, which is specific to Chernobyl, is also general in its framing. It captures acute and long-term and direct and indirect effects. Some of the economic consequences are obvious: destruction of the plant(s); the costs of managing the accident, including decommissioning the plant and decontaminating surrounding areas; and destruction and loss of property, e.g., loss of agricultural products. Others are less obvious, even though potentially long-lasting: loss of economic opportunities, out-migration, and long-term neuropsychological consequences.

This report focuses on the costs of the Chernobyl disaster. Several reports provide general, but incomplete frameworks for assessing the costs of nuclear power plant accidents. One early but frequently quoted study on the costs of nuclear power plant accidents was released in 1982 by the US Sandia National Laboratory. That study (*Estimates of the Financial Consequences of Nuclear Power Reactor Accidents*) was intended to assess the financial consequences of possible accidents at U.S. nuclear power plants existing at the time (Strip, 1982). For that purpose, a model was used (Calculation of Reactor Accident Consequences, Version 2 or CRAC2) that had been developed to guide siting of plants. Five scenarios of severity were

incorporated into the analysis. The range of consequences considered was restricted and did not incorporate, for example, onsite costs, full costs of health damages, and indirect costs. The health consequences addressed were early deaths and injuries, and longer-term cancer fatalities. Appropriate discounting was incorporated in estimating future costs to take account of present costs versus future consumption. Subsequent to this report, which offered a limited framework for addressing costs of a nuclear power plant accident, a more refined and broader framework and model has apparently not been developed for the US, leaving this 1982 document as a widely cited report.

A 2000 report from the Organisation for Economic Co-operation and Development (OECD) addressed methodologies for estimating the costs of nuclear accidents (Organization for the Economic Co-operation and Development & Nuclear Energy Agency, 2000). This expert report reached the overall conclusion that: "The Group reached very early a consensus on the conclusion that there is no single "cost of an accident," i.e., that there is no single correct cost to be estimated. With regard to health costs, the report acknowledged the importance of neuropsychological consequences and the difficulty of costing them. It addressed methodological issues around the estimation of health costs. While the report acknowledged unresolved methodological issues, a follow-up report by OECD addressing these issues was not identified by our literature search, although a study is apparently being conducted by an expert group on costs of nuclear accidents, liability issues and their impact on electricity costs (Organization for the Economic Co-operation and Development & Nuclear Energy Agency, 2014).

A more recent and comprehensive approach is described in the United Kingdom's Health Protection Authority (now Public Health England) report: *COCO-2: A Model to Assess the Economic Impact of an Accident* (Higgins et al., 2008). COCO-2 is a model for addressing the off-site costs following a nuclear accident. As we have done in the review in this report, the model examines costs in the categories of direct and indirect and provides a very clear framework for the paths by which an accident could directly lead to costs (Figure 3). It considers medical costs, but does not capture the potential costs of neuropsychological effects, including those that may be subclinical, i.e., not leading to health care and to a clinical diagnosis, but widespread. In setting out its methodology, the report identifies the diverse data streams needed for comprehensively estimating some of the health costs that would follow a nuclear power plant accident.

Another generic approach uses a general cost figure per person-rem of exposure. For example, the U.S. Nuclear Regulatory Commission (NRC) determines the monetary value of a person-rem using a conversion factor. This factor was recently revised to $5100 per person-rem, calculated by multiplying the value of a statistical life (currently determined to be $9 million) by a nominal risk coefficient (5.7×10^{-4}) per person-rem (U.S. Nuclear Regulatory Commission, 2015). NRC also developed MELCOR Accident Consequence Code System Version 2, a computer code that evaluates offsite consequences. The code models atmospheric transport and dispersion, emergency response actions, exposure pathways, health effects, and economic costs, following

four steps for estimating consequences (U.S. Nuclear Regulatory Commission & SECY Commission, 2012).

Absent an existing standard framework for comprehensively capturing direct and indirect costs, we have outlined the potential sources of costs, stratifying them by timeframe (short- or long-term) and mechanism (direct or indirect) (Table 1). Table 1 sets out sources of direct costs, separated by time domain with short-term referring to days, months, and even years; for example, at Fukushima the situation with the damaged reactors and leakage of contaminated water continues over five years after the tsunami and ensuing core meltdowns (Normile, 2016). Looking to the long-term consequences, we consider some as extending for decades and potentially across generations. At Chernobyl, land in the Exclusion Zone, which covers approximately 2,600 km^2, has been withdrawn from use for almost five decades. Costs related to Reactor Unit 4 continue, as the New Safe Confinement is under construction to replace the original sarcophagus. Table 1 similarly includes indirect costs. Some of these are immediate, e.g., disruption of medical services, for example unexpected emergency closure of hospitals that may be providing life-sustaining care for ill individuals, while others may be lasting, e.g., the costs of sustained anxiety and depression and loss of jobs. Thus, indirect costs are also ongoing and include increased disease burden and life-shortening, all bringing costs that are typically linked to disasters more generally.

We preliminarily looked at costs related to the Chernobyl disaster in our 2013 Report prepared for Green Cross Switzerland (Samet & Patel, 2013). The estimates reviewed in the 2013 report,

which were identified through a search of studies available at the time, are listed in Appendix A. The patchwork of estimates and variable methodologies anticipated problems encountered in the present review. Building upon that report, we have undertaken a comprehensive literature review to identify information on the costs of the Chernobyl disaster, set within the framework offered by Figure 1-3 and Tables 1. That framework implies what is needed to estimate the overall costs of the disaster—an accounting of costs reflecting an array of consequences that begins at the time of the disaster and extends to the present and beyond. For the Chernobyl disaster, there is the further challenge posed by the extent of the spread of radiation and the multiple countries affected, along with the sweeping geopolitical changes affecting the region since the disaster in 1986. Any accounting is further complicated by the multiple economies and currencies involved and their changing values over time.

Here, we present the findings of a comprehensive review of the extant literature and recommendations on what should be done to provide a broader and more certain estimation of the financial value of the overall negative consequences of the disaster. Such understanding is need for a deeper societal appreciation of the costs of nuclear power, which must reflect not only the costs of construction, operations, and decommissioning, but of any accidents. This report complements our previous reports prepared for Green Cross Switzerland that addressed the long-term health consequences of the disaster, including neuropsychological and chronic disease outcomes (Samet & Chanson, 2014; Samet & Patel, 2011; Samet & Patel, 2013).

Methods

A systematic approach was used to search for information on the economic costs of the Chernobyl disaster. The databases PubMed, LexisNexis, and Google Scholar were initially used to search for any academic studies conducted on this topic, as well as government and agency reports. Multiple searches were carried out with various search strings, including: "cost of nuclear disaster/accident," "economic cost of nuclear disaster/accident," and "economic cost of Chernobyl." Results for LexisNexis were limited to the category of law reviews and journals. Due to the volume of search results found in Google Scholar, the first 100 results were examined for their applicability. Publication titles were initially screened for relevance, after which abstracts were selected for further review. Table 2 includes the list of search queries executed, the numbers of results returned, and the numbers of abstracts reviewed.

As these searches did not yield many applicable results, other approaches were utilized. Searches on the costs of Chernobyl were conducted using the search engine Google (first 100 results) to identify publications that are not found in the scientific literature. Additionally, reference lists of selected articles were reviewed. Finally, based on author knowledge, websites related to nuclear energy were searched to find any relevant sources. To be included in this report, sources had to be published in a government or agency report, book, or peer-reviewed journal article; written in English; and available for full article access. In a future report, we will look more broadly and cover non-English language reports. All cost figures in our report are provided in US dollars. Figures that were given in rubles were coverted to US dollars using the average of exchange rates at the end of each year for the time period covered

in the estimate (The Central Bank of the Russian Federation (source); Wikipedia & Archive of Bank of Russia (source)).

Findings

The various search engines selected large numbers of potentially relevant citations and links, but few of those identified proved applicable on review (Table 2). After consideration of titles and abstracts, a total of 20 reports was identified that provided some information on the costs of the Chernobyl accident. These reports are listed in Table 3, which describes their origins, and the country and time period of the estimates. Further and lengthier description of the methods of each report is provided in Appendix B. Table 4 provides further details on the cost estimates, breaking them down by categories, as available.

Table 3 highlights the diversity of the estimates of the financial value of the adverse consequences. They have been made by a variety of agencies, cover different time periods, and relate to various countries. For many of the estimates, as noted in Appendix B, the methodology is poorly described and some of the reports cite documents that could not be obtained for examination. Some of the cost figures reflect actual expenditures while others are cost estimates. Not surprisingly, the figures range widely as a result. The estimates correspond to some of the categories in Table 1, but only a few comprehensive estimates are provided.

Table 4 provides more detailed information concerning the figures, giving them within specific categories when possible. The categories listed for the various reports are as stated within the

reports, without any effort to standardize across reports. The figures cover a wide range, depending on category, timeframe and country. Estimates of aggregate costs at the 25-year anniversary are over USD $100B for Ukraine and Belarus.

Some costs directly related to the plant can be assembled. Drawn from reports listed in Table 4, Table 5 lists the available costs related to the plant itself. These costs primarily include decontamination, cleanup, and disposal of radioactive material. The figures are provided for Ukraine and Belarus; covering a wide range of timeframes, the estimates are similarly varied. Additionally as previously mentioned, one of the ongoing costs related to the plant is the construction of the New Safe Confinement. According to recent estimates, costs of the Shelter Implementation Plan, of which the New Safe Confinement is included, are estimated to be $2-3 billion at the time the estimate was provided in 2014 (Becker, 2015; European Bank for Reconstruction and Development; World Nuclear News, 2015).

Also drawn from Table 4 are costs related to public health and medical care for affected populations, outlined in Table 6. These costs include public health protection measures, specialized medical care, and psychological support. Similar to the previous table, the figures cover a range of countries, timeframes, and cost estimates. The later figures for Ukraine and Belarus, which reach approximately $100B for health costs, merit particular attention, given the time periods covered, 11 years and 30 years, respectively.

Comment

This review of the literature documents a patchwork of cost estimates and expenditure figures, covering a variety of consequences of the Chernobyl disaster for various countries and at various time intervals (see Appendix C, which displays selected estimates, the category of the estimates, and the timeframe of the estimates). The literature does not yield a cumulative estimate of either total costs or of costs within specific categories; this lack of information on a matter of high importance to many stakeholders, particularly the general population, is not surprising, given the complexities of accurately tracking the full array of consequences and their costs over time (Table 1). And, of course, the affected countries experienced major disruptions over the 30 years since the disaster, leading to further stresses on the affected populations and interruptions of care services, as well as leaving gaps in the data needed for cost estimation. Undoubtedly, population health tracking was also adversely affected, including documentation of the health status of the population, medical care utilization, and the occurrence of depression and anxiety.

Neuropsychological consequences are acknowledged as the most widespread and perhaps most costly long-run consequence of the Chernobyl disaster (Bromet, 2012, 2014; Bromet, Havenaar, & Guey, 2011; Samet & Patel, 2013; The Chernobyl Forum, 2003-2005; World Health Organization, 2006). Additionally, depression is projected to become a leading cause of disease burden and the countries of Eastern Europe and Russia in particular have had notably high rates of depression, suicide, and alcoholism (Global Burden of Disease Study 2013 Collaborators, 2015; Leon, Shkolnikov, & McKee, 2009; Roberts, Abbott, & McKee, 2010; Stickley et al., 2015;

Tomkins et al., 2012). The cost estimates reviewed did not appear to incorporate local data that would have captured the full scope of the neuropsychological consequences and their possible persistence over time.

At best, the existing estimates indicate that the total costs at the 30-year mark after the disaster must be very high. Additionally, there is great uncertainty for some categories, as many estimates have been reported without sufficient available documentation and assumptions are inherently needed to make them. Many of these estimates came from government agencies and presumably were based in government data resources, but we could not find documentation as to their basis in general. Reports of actual expenditures constitute the most accurate type of information, but are limited.

Table 1 outlines some indicators that might have been tracked to have more complete information on the costs of the disaster. The ideal is usefully considered: compiling data on the various indicators from the time of the disaster forward, as costs in some of the categories are ongoing. Consider the additional health costs resulting from the disaster, which would reflect: immediate injuries and deaths; short-term and long-term neuropsychological consequences; excess radiation-related cases of cancer; increased risk for other noncommunicable diseases; and reduction of life expectancy. Estimation of such costs would require basic population health statistics (demographics, birth rates, and mortality rates), surveillance for neuropsychological consequences over time, and information on the costs of health care and other services (e.g., social services). Absent direct information of the costs of the

neuropsychological sequelae, an assumption-based estimation approach would be needed. Risk assessment approaches and lifetable methods would be employed to calculate additional cases of cancer and other diseases, as well as life-shortening. Such calculations would be based on modeling of the radiation doses received by the populations reached by radiation from the disaster, projection of the associated risks of cancer and other diseases using standard risk estimates (e.g., from the atomic-bomb survivors study), and estimation of the associated costs of the additional disease.

Nonetheless, we can make some general comments about the costs by major category based on the data available. First, regardless of uncertainties, the information tabulated shows clearly that the indirect and long-terms costs far exceed the immediate and direct costs. Health costs represent the largest proportion of the indirect costs, particularly when consideration is given to the long-time period over which these costs are manifest—amounting to the full lifespans of those exposed and possibly extending to the next generation. Second, although the costs of clean-up and maintenance are the most certain and substantial, they are far lower than the indirect costs. Third, simply extending some of the estimates to cover the full 30 years since the disaster leads to notably high estimates.

Based on the estimates found in our review, we have made extrapolations to gauge approximately the costs that may have been incurred by the Chernobyl nuclear power plant accident to date. Clearly, the estimates gathered are limited by the degree of documentation, the range of costs covered, and their geographic and temporal coverage. For Belarus, there is a

national estimate of $235B for 1986-2015 attributed to “aggregate damage” and for Ukraine, there is a 25-year estimate for “total economic loss” of $198B. Scaled to 30 years, the Ukraine estimate of around $240B is quite comparable to that for Belarus. In our 2013 report, we identified a population of 10,000,000 as “exposed” in a relatively broad sense to radiation and the disaster, approximately one-third each from Russia, Ukraine, and Belarus. Thus, tripling either the Ukraine or Belarus 30-year estimates to cover the full exposed population leads to a total of around $700B in costs for the 30 years, assuming the same cost figures apply to Russia. This estimate involves a number of assumptions and must be considered as uncertain, but it is based on governmental figures. However, regardless of the inherent uncertainty the figure is high and existing estimates would support overall costs of hundreds of billions. Of course, the costs will continue to mount, reflecting the need to maintain the plant, the withdrawn land, and persistent health consequences. However, there is too much uncertainty about how these costs will play out over time to proportionately extrapolate them to the 50-year mark and beyond.

In interpreting the estimates developed in this report, consideration needs to be given to the perspectives of those paying for and of those bearing the costs. Key stakeholders include: the organization responsible for the plant (formerly the Soviet Union and now Mintopenergo Of Ukraine - Ministry Of Fuel And Energy Of Ukraine), those injured and deceased, local property owners, the displaced population, the governments of countries reached by the radiation and sustaining economic and health costs, and the populace at large. In the case of the Chernobyl disaster there was concern across much of Europe and even globally because of the amount of

radiation released and its wide dissemination. Some stakeholders have paid directly, e.g., the governments that have covered the costs of containment, clean-up, and site maintenance, and now the New Safe Confinement, which is supported by the involved nations, the European Union, the United States, and others (European Bank for Reconstruction and Development; European Commission, 2015; World Nuclear News, 2015). For those displaced, there has been some compensation and social welfare programs have been established and health care provided to an extent. However, these individuals have likely experienced far greater losses through economic disruption and ongoing neuropsychological sequelae. From the economists' perspective, such compensation payments represent a transfer and not an accountable cost of the disaster. Nonetheless, our prior focus groups among Chernobyl-affected groups suggest that many consider themselves and their children as still damaged and not adequately compensated or cared for several decades after the accident.

The generalizability of the estimates reviewed in this report needs to be considered. The disaster took place 30 years ago and involved a government owned and operated power plant in a Communist country. The management of the disaster and the affected populations would likely be different in other countries in today's environment. In some countries, for example, the United States, there would undoubtedly be substantial litigation following a nuclear power plant disaster.

The lack of comprehensive estimates for the 30-year period merits comment. Over time, various governmental agencies and other organizations have developed estimates (Table 4).

However, none have taken responsibility for assuring that there is ongoing collection of data needed for cost estimation. While that task would have been extraordinarily challenging under the circumstances around and following the Chernobyl disaster, arguably the necessary information should have been collected to assure that the best understanding possible was gained of the costs of the disaster. This failing is one key "lesson learned" with applicability to the Fukushima disaster, now at the five-year mark.

Acknowledgements

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Figure 1: Cost and Consequences of Nuclear Accidents Over Time

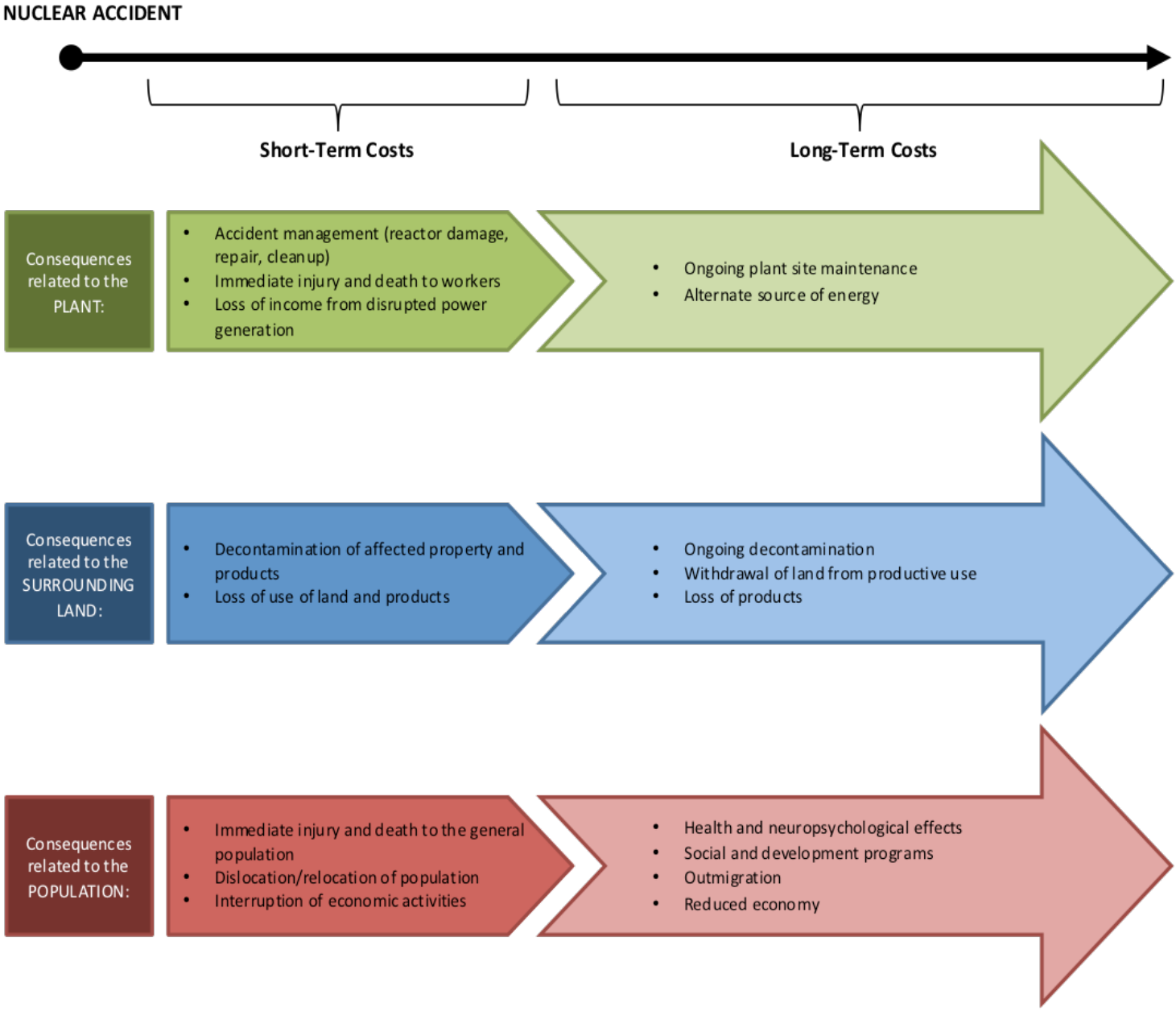

Figure 2: Interaction Among Health, Social, and Economic Effects (adapted from UNDP 2002)

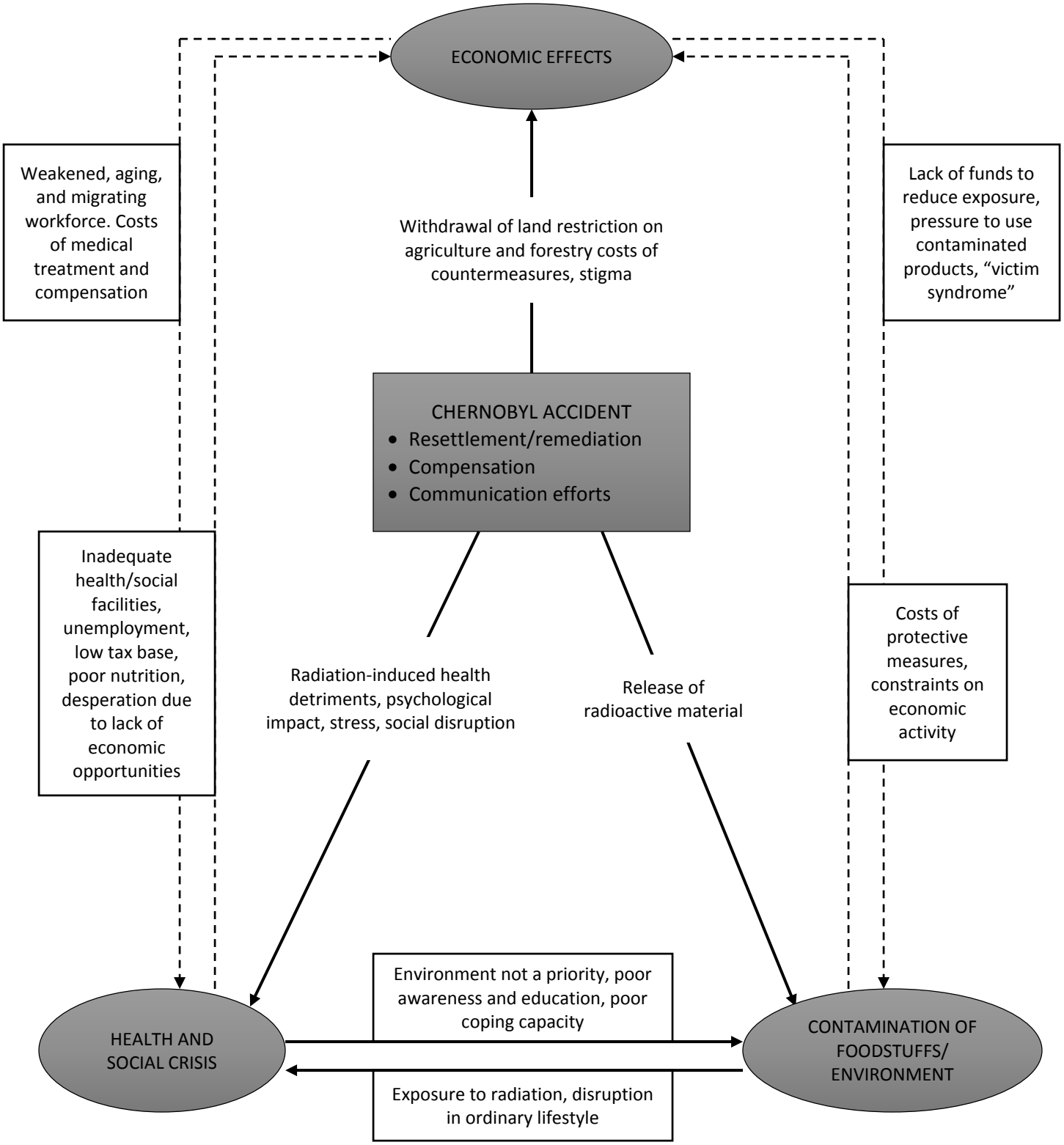

Figure 3: Schematic Representation of How Direct Effects of an Accident Impact a Range of Economic Effects (adapted from Higgins et al. 2008)

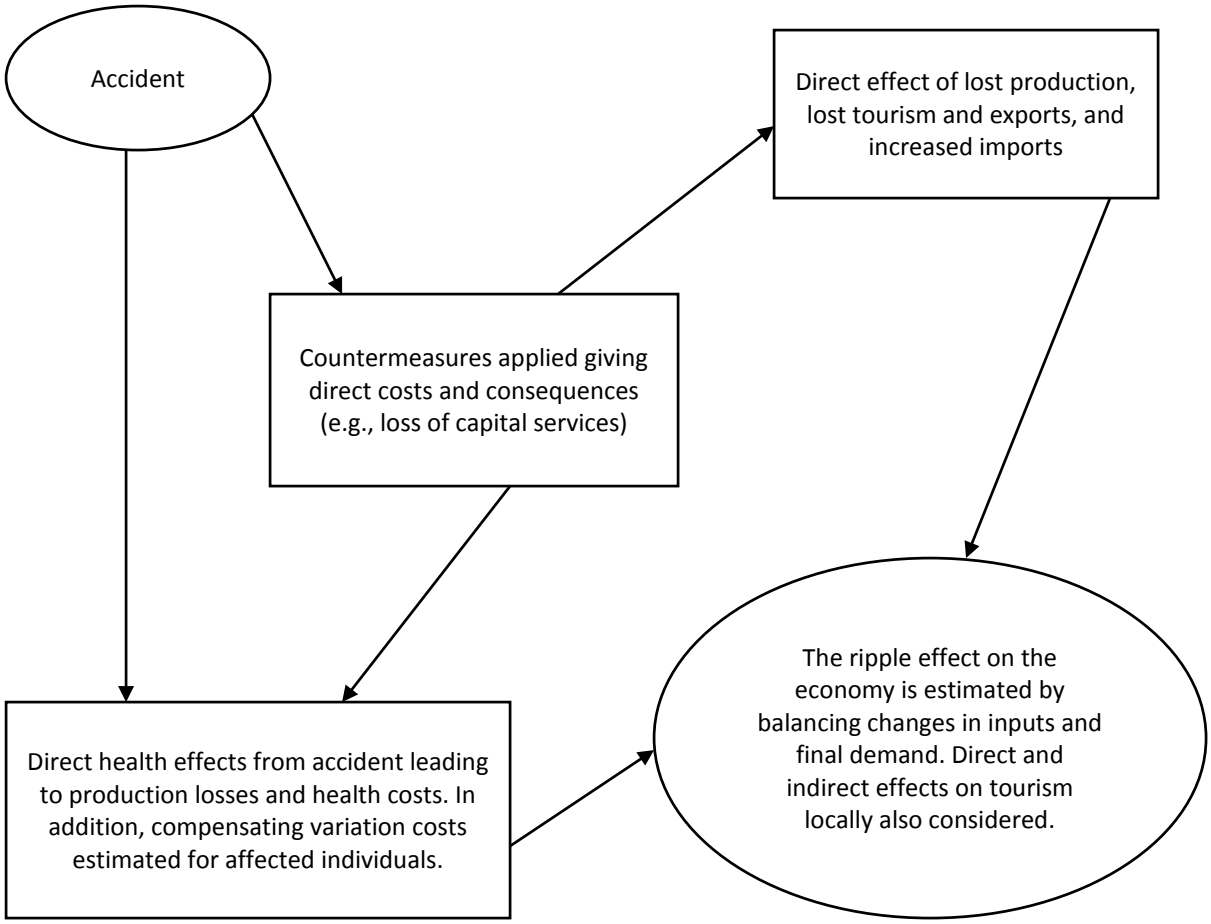

Table 1: Approaches to Cost Estimation for the Chernobyl Disaster

DIRECT COSTS	
Short-Term	
Source of Cost	*Indicator*
Costs of damage to the plant	➢ Replacement costs for the plant
Costs of cleanup of the plant	➢ Expenditures on cleanup and decommissioning
Lost income from the plant closure	➢ Estimated income over projected period of operation
Contaminated/damaged property and products	➢ Value of land made unusable; value of damaged products (e.g., discarded agricultural products)
Immediate injury and death	➢ Costs of medical care and compensation; cost of premature death
Long-Term	
Source of Cost	*Indicator*
Withdrawal of land from productive use – Exclusion zone	➢ Value of goods that would have been produced from natural resources, agriculture, manufacturing
Plant site maintenance	➢ Actual expenditures
Ongoing decontamination activities	➢ Actual expenditures
INDIRECT COSTS	
Short-Term	
Source of Cost	*Indicator*
Disruption of key services	➢ Costs of additional medical care; premature deaths costed per life lost; fines
Dislocation/relocation of populations	➢ Costs of lost housing and goods; costs of relocation and alterative housing
Interruption of economic activities	➢ Costs of lost productivity and manufacturing beyond the zone immediately affected by radiation
Long-Term	
Source of Cost	*Indicator*
Loss of economic activity	➢ Shrinkage of the local economy
Out migration	➢ Loss of productive workers
Health consequences, including neuropsychological sequelae	➢ Costs of additional medical care; costs of premature mortality; costs of disability and impairment; social costs (e.g., crime, violence, suicide)

Table 2: List of Search Queries

Database / Search Engine	Search Terms	Date Searched	Total Results	Abstracts Reviewed*
PubMed	"cost of nuclear disaster"	12/23/15	66	5
	"cost of nuclear accident"	2/24/16	140	6
	"economic cost of nuclear disaster"	12/23/15	50	4
	"economic cost of nuclear accident"	2/24/16	93	5
	"economic cost of Chernobyl"	12/23/15	46	4
LexisNexis	"cost of nuclear disaster"	1/6/15	1	1
	"cost of nuclear accident"	2/24/16	1	1
	"economic cost of nuclear disaster"	1/6/15	1	1
	"economic cost of nuclear accident"	2/24/16	4	2
	"economic cost of Chernobyl"	1/6/15	5	2
Google Scholar	"cost of nuclear disaster"	1/11/15	226,000†	4
	"cost of nuclear accident"	2/24/16	192,000†	5
	"economic cost of nuclear disaster"	1/11/15	220,000†	2
	"economic cost of nuclear accident"	2/24/16	201,000†	11
	"economic cost of Chernobyl"	1/11/15	34,900†	14

*Includes some duplicates

†Reviewed first 100 search results

Table 3: Overview of Reports Providing General Economic Costs

Reference Source	Title	Cost Description	Date of Estimate	Region of Estimate	Cost Amount
Science – Anspaugh, Catlin, Goldman (1988); *cited from*: Proceedings of an All-Union Conference – IAEA (1988)	The Global Impact of the Chernobyl Reactor Accident	Total estimated cost	*[Information not provided]*	*[Information not provided]*	$15 billion
Environment International – Steinhausler, Hofmann, Daschil, Reubel (1988)	Chernobyl and its Radiological and Socio-economic Consequences for the Province of Salzburg, Austria	Costs due to direct and indirect damages related to fallout contamination	1986-1987	Salzburg, Austria	$5.6 million
Medvedev (1990)	The Legacy of Chernobyl	Cost of the accident	1989	Soviet Union	$20 billion
		Indirect losses	1986-1987	Eastern/ Western Europe	$1-1.5 billion
		Economic cost (losses) of Chernobyl	1987	*[Information not provided]*	$11.9 billion*
		Direct and indirect cost of accident	1988	Belarus	$3.16 million*
		Assistance programme for people living in contaminated districts	1988-1989	Belarus	$487.2 million*
The Geneva Papers on Risk and Insurance – Faure and Skogh (1992)	Compensation for Damages Caused by Nuclear Accidents: A Convention as Insurance	Direct loss	*[Information not provided]*	Soviet Union	$15 billion
One Decade After Chernobyl: Summing up the Consequences of the Accident, Proceedings of an International Conference, sponsored by IAEA et al. (1996) – Voznyak; Rolevich, Kenik, Babosov, Lych	Social, Economic, Institutional and Political Impacts (Background Paper 6): Report for the Soviet Period, Report for the Russian Federation, Report for Belarus, Report for Ukraine	Total direct losses and outlays	1986-1989	*[Information not provided]*	$14.1 billion*
		Total direct losses and outlays	1986-1991	*[Information not provided]*	$37.8 billion*
		Costs of mitigating consequences	1992-1995	Russia	$1.4 billion†
		Expenditures for the "Unified State Programme on Protection of the Population of the Russian Federation from the Consequences of the	1992-1995	Russia	$1.2 billion†

		Chernobyl Accident"			
		Expenditures for the federal programme "Children of Chernobyl"	1992-1995	Russia	$71.8 million[†]
		Economic damage	1986-2015	Belarus	$235 billion
		Direct losses from withdrawing land from agricultural use		Belarus	$15.2 billion
		Loss in gross output from agricultural production		Belarus	$10.3 billion
		Loss of basic production and working funds		Belarus	$0.9 billion
		Direct production losses in private subsidiary small holdings		Belarus	$400 million
Ten Years After the Chernobyl Catastrophe, Proceedings of International Conference, sponsored by UNESCO et al. (1996) – Lych, Pateeva	Economic Effects of the Chernobyl Disaster: Estimation and Minimization Problems	Total economic damage	1986-2015	Belarus	$235 billion
Journal of Environmental Radioactivity – Tveten, Brynildsen, Amundsen, Bergan (1998)	Economic Consequences of the Chernobyl Accident in Norway in the Decade 1986-1995	Total costs of mitigating actions	1986-1995	Norway	$70 million
Report by UNDP and UNICEF with UN-OCHA and WHO (2002)	The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery	Budget expenditures	1992-2000	Ukraine	$5.4 billion
		Estimated losses	Over 30 years	Belarus	$235 billion
		Estimated losses	1986-2000	Ukraine	$148 billion
The Chernobyl Forum (2003-2005)	Chernobyl's legacy: Health, Environmental, and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine	Total losses	Over 30 years	Belarus	$235 billion
		Total spending	1991-2003	Belarus	$13 billion
Chernobyl: Catastrophe and Consequences – Bay and Oughton (2005);	Chapter 7: Social and Economic Effects	Total estimated expenditures	1986-2016	Belarus	$235 billion
		Expenditures	1986-2000	Ukraine	$148 billion
		Expenditures	1992-1998	Russia	$3.8 billion

cited from: EMERCOM (2001), IEBNAS (2001), UNDP (2002)		Expenditures	2000	Ukraine	$332 million
National Report of Ukraine (2006)	20 Years after Chornobyl Catastrophe: Future Outlook	Total sum of direct losses and expenses	1986-1989	Soviet Union	$12.6 billion
		Direct losses in exclusion zone	1986	Ukraine	$1.385 billion
		Direct losses outside exclusion zone	1986	Ukraine	$0.84 billion
		Costs of eliminating consequences	1986-1997	Ukraine	$23 billion
		Indirect losses		Ukraine	$163.74 billion
		Total economic loss	2005	Ukraine	$179.05 billion
Energy Policy – Sovacool (2008)	The Costs of Failure: A Preliminary Assessment of Major Energy Accidents, 1907-2007	Property damage costs	*[Information not provided]*	Ukraine	$6.7 billion
National Report of Ukraine (2011)	Twenty-five Years After Chornobyl Accident: Safety for the Future	Total direct losses and expenses	1986-1989	Soviet Union	$12.6 billion
		Total direct loss within exclusion zone	Evaluated in 1986	Ukraine	$1.385 billion
		Total direct loss outside exclusion zone	Evaluated in 1986	Ukraine	$0.841 billion
		Total sum of direct expenses	1986-2010	Ukraine	$30 billion
		Total amount of indirect loss	Over 30 years, until 2015	Ukraine	$163.74 billion
		Total economic loss	As of 2010	Ukraine	$198 billion
National Report of the Republic of Belarus (2011)	A Quarter of a Century after the Chernobyl Catastrophe: Outcomes and Prospects for the Mitigation of Consequences	Aggregate damage	1986-2015	Belarus	$235 billion
AMBIO – Hogberg (2013)	Root Causes and Impacts of Severe Accidents at Large Nuclear Power Plants	Total costs	Over first 25 years	*[Information not provided]*	$250-500 billion

Cost figures provided in rubles were converted to US dollars by the following:

*Calculated using the average of official exchange rates for years 1986-1989 (.6437 RUB = 1 USD) / 1986-1991 (.6304 RUB = 1 USD).

†Calculated using the average of rates at the end of the year for years 1992-1995 (2463 RUB = 1 USD).

Table 4: Findings of Reports Providing Costs in Specific Categories

Reference Source	Title	General Cost Description	Specific Cost Categories	Cost Amount
Science – Anspaugh, Catlin, Goldman (1988); *cited from*: Proceedings of an All-Union Conference – IAEA (1988)	The Global Impact of the Chernobyl Reactor Accident	Total estimated cost	Direct cost (e.g., loss of the reactor, relocations, medical care, decontamination)	$6.8 billion
			Indirect costs (e.g., replacement of lost power, new construction, food surveillance)	$6.8 billion
			Additional costs in other countries	$1.4 billion
Environment International – Steinhausler, Hofmann, Daschil, Reubel (1988)	Chernobyl and its Radiological and Socio-economic Consequences for the Province of Salzburg, Austria	Direct damages related to fallout contamination: Salzburg, Austria – 1986-1987	Vegetable farming	$270,000
			Sheep and goat farming	$300,000
			Additional supply of uncontaminated fodder for cattle and sheep	$810,000
			Whey production and disposal	$390,000
			Stock farming	$110,000
			Milk Industry	$3,040,000
			Fruit farming	$8,000
			Measurement equipment for slaughter houses	$8,000
		Indirect damages related to fallout contamination: Salzburg, Austria – 1986-1987	Vegetable farming	$210,000
			Strawberry farming	$480,000
			Sheep farming	$15,000
			Game hunting	$6,000
Medvedev (1990)	The Legacy of Chernobyl	Indirect losses: Eastern/Western Europe	Losses from food ban in Eastern Europe (1986)	$300 million
			Compensation paid to farmers in Hungary	$10 million
			Compensation paid to farmers in Britain	$10 million
			Compensation paid to farmers in Austria	$70 million
			Compensation paid to farmers in West Germany	$100 million
One Decade After Chernobyl: Summing up the Consequences of the Accident, Proceedings of an International Conference, sponsored by IAEA et al. (1996) – Voznyak; Rolevich, Kenik, Babosov, Lych	Social, Economic, Institutional and Political Impacts (Background Paper 6): Report for the Soviet Period, Report for the Russian Federation, Report for Belarus, Report for Ukraine	Expenditures for the "Unified State Programme on Protection of the Population of the Russian Federation from the Consequences of the Chernobyl Accident": Russia – 1992-1995	Public health protection and provision of specialized medical care	$17.8 million†
			Monitoring of radioecological situation and establishment of information support system	$2.4 million†
			Measures for exclusion zone and area of compulsory evacuation	$0.17 million†
			Measures to reduce the dose commitment to the population, including agro-industrial and forestry measures	$9.6 million†
			Social and socio-psychological rehabilitation of the population	$2.2 million†
			Economic rehabilitation of the	$3.3 million†

			areas	
			Scientific support	$2.7 million†
			International cooperation	$0.09 million†
			Cooperation with public organizations and information support for the population	$0.15 million†
			Management of work on implementing programme measures	$0.07 million†
			Information and analytical support	$1.4 million†
			Reserve (used for unforeseen expenditure)	$0.02 million†
			Capital investments in the production sector	$113.7 million†
			Capital investments in the non-production sector	$337.8 million†
			Social protection of the population (payment of compensation and granting of privileges)	$752.6 million†
		Expenditures for the federal programme "Children of Chernobyl": Russia – 1992-1995	Provision of medical care to children and pregnant women	$3.4 million†
			Measures for the provision of uncontaminated food to children, pregnant women and nursing mothers	$0.72 million†
			Treatment of children	$0.71 million†
			Medical and social support for disabled children in boarding schools	$1.3 million†
			Psychological support for children	$3.3 million†
			Scientific support	$0.46 million†
			Capital investments	$61.6 million†
		Damages: Belarus – 1986-2015	Direct and indirect losses	$29.6 billion
			Additional expenditure associated with coping with consequences of accident	$191.7 billion
			Damage to forestry	$4 billion
			Damage to social sector	$14.2 billion
			Damage to construction industry	$2.7 billion
			Damage to transport and communications sector	$3.4 billion
Ten Years After the Chernobyl Catastrophe, Proceedings of International Conference, sponsored by UNESCO et al. (1996) – Lych,	Economic Effects of the Chernobyl Disaster: Estimation and Minimization Problems	Total economic damage: Belarus – 1986-2015	Total damaged caused by disaster	$70 billion
			Losses of processing industries of Agrarian and industrial complex	$2.7 billion
			Losses in forestry industry	$4 billion
			Damage to social sphere	$14.2 billion
			Losses to housing and communal services	$3.5 billion
			Damage caused to people's health	$1.9 billion

Pateeva			Resettlement of population from contaminated regions	$5 billion
			Social protection of citizens	$86 billion
			Treatment of contaminated areas	$12.85 billion
			Organization and maintenance of radioecologic monitoring service	$1.7 billion
Journal of Environmental Radioactivity – Tveten, Brynildsen, Amundsen, Bergan (1998)	Economic Consequences of the Chernobyl Accident in Norway in the Decade 1986-1995	Total costs of mitigating consequences to Norwegian agriculture: Norway – 1986-1995	Lettuce/parsley	$45,000
			Beef	$711,000
			Goats cheese	$2.4 million
			Sheep	$52.1 million
			Reindeer	$15.7 million
Journal of Environmental Radioactivity – Nisbet, Woodman (2000)	Options for the Management of Chernobyl-restricted Areas in England and Wales	Indirect damage costs: England/Wales	Compensating farmers for inspection and monitoring of sheep related to radioactive contamination (£1.3/sheep)	$1.83/sheep
			Cost incurred when selling marked sheep (£6.5/sheep)	$9.08/sheep
Report by UNDP and UNICEF with UN-OCHA and WHO (2002)	The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery	Budget expenditures: Ukraine – 1992-2000	Social protection	$3450.6 million
			Special medical care	$97 million
			Scientific research	$45.2 million
			Radiation control	$44.6 million
			Environmental recovery	$1.55 million
			Radiological rehabilitation and radioactive material disposal	$1.55 million
			Resettlement, housing and living conditions improvement	$1374.2 million
			Exclusion zone maintenance	$330.5 million
			Other expenditures	$159.4 million
Chernobyl: Catastrophe and Consequences – Bay and Oughton (2005); *cited from*: Report by UNDP and UNICEF with UN-OCHA and WHO (2002)	Chapter 7: Social and Economic Effects	Expenditures: Ukraine – 2000	Social protection	$290 million
			Special healthcare to affected population	$6.4 million
			Scientific research on environment, health, production of clean food	$1.8 million
			Radiation control	$2.7 million
			Environmental recovery	$0.04 million
			Radioecological improvement of settlements, disposal of radioactive waste	$0.05 million
			Resettlement and improvement of living conditions	$13.74 million
			Actions to mitigate consequences in exclusion zone	$17.4 million
			Other	$0.4 million
National Report of Ukraine (2006)	20 Years after Chornobyl Catastrophe: Future Outlook	Costs of eliminating consequences: Ukraine – 1986-1997	Social protection of people	$9048.01 million
			Special medical help	$121.8 million
			Scientific research	$93.93 million
			Radiation control	$82.69 million
			Environment and ecological	$1.16 million

			recovery costs	
			Rehabilitation provision and burial of radioactive wastes	$1.3 million
			Investments, resettlements and ensuring proper living on the contaminated territories	$4304.16 million
			Conducting work in the exclusion zone	$9168.87 million
			Other costs	$410.78 million
		Indirect losses: Ukraine	Misuse of agricultural lands, water, and forestry resources	$68.37 billion
			Value of the deficiency of electrical energy production	$28.05 billion
			Losses due to moratorium on new reactor units at existing atomic power plants	$67.32 billion
Cited in: Economics of Security Working Paper Series – Ramseger, Kalinowski, Weiβ (2009)	CBRN Threats and the Economic Analysis of Terrorism	Recovery, reconstruction, restoration: Ukraine	Cleaning activities, decontamination and building of the sarcophagus, over 20,000 new houses, and 15,000 flats	$17 billion
		Indirect damage costs	Macroeconomic loss of Belarus – 1986-2015	$235 billion
			Loss in Sweden related to agriculture and cattle breeding	$145 million
			Cost per year by Norwegian government for measuring radioactivity in meat	$3 million/year
			Concession to losses by cattle breeding, agricultural and horticultural industries from German government	$300 million
			Processing of contaminated milk by German government	$44 million
			Damages in farming	$0.71 million
National Report of Ukraine (2011)	Twenty-five Years after Chornobyl Accident: Safety for the Future	Total direct loss within exclusion zone: Ukraine – in 1986	Loss of tangible objects	$1.339 billion
			Disposed vehicles and equipment, activities	$.046 billion
		Total amount of indirect loss: Ukraine – over 30 years, until 2015	Disused agricultural lands, forest areas, and water resources	$68.37 billion
			Cost of non-generated electric energy	$28.05 billion
			Moratorium on operating NPP's power development	$67.32 billion
		Total economic loss: Ukraine – as of 2010	Direct losses of tangible objects and objects of economy	$2 billion
			Direct expenses to financing activities and works to eliminate accident consequences	$18 billion
			Indirect loss due to prescheduled shutdown of NPP	$178 billion
National Report of the Republic of	A Quarter of a Century after	Aggregate damage: Belarus – 1986-2015	Costs of maintaining the industry and implementing protective	$191.7 billion

Belarus (2011)	the Chernobyl Catastrophe: Outcomes and Prospects for the Mitigation of Consequences		measures	
			Direct and indirect losses	$30 billion
			Loss of profit	$13.7 billion
		Aggregate damage: Belarus – 1986-2015	Public health	$93.27 billion
			Agro-industry	$72 billion
			Forestry	$4.11 billion
			Industry	$0.63 billion
			Construction	$2.68 billion
			Mineral, raw materials and aquatic resources	$2.67 billion
			Transport and communication	$3.39 billion
			Social sector	$17.70 billion
			Decontamination of contaminated areas	$36.83 billion
			Radiological monitoring	$1.72 billion

Cost figures provided in rubles were converted to US dollars by the following:

[†]Calculated using the average of rates at the end of the year for years 1992-1995 (2463 RUB = 1 USD).

Table 5: Costs Directly Related to the Plant

Source	Plant-Related Cost Description	Cost Amount
Lych and Pateeva (1996) – Economic Effects of the Chernobyl Disaster: Estimation and Minimization Problems, *in: Ten Years After the Chernobyl Catastrophe*	Treatment of contaminated areas (Belarus, 1986-2015)	$12.85 billion
UNDP, UNICEF, UN-OCHA, WHO (2002) – Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery	Radiological rehabilitation and radioactive material disposal (Ukraine, 1992-2000)	$1.55 million
Bay and Oughton (2005) – Social and Economic Effects, *in: Chernobyl: Catastrophe and Consequences*	Radioecological improvement of settlements, disposal of radioactive waste (Ukraine, 2000)	$0.05 million
National Report of Ukraine (2006) – 20 Years after Chornobyl Catastrophe: Future Outlook	Rehabilitation provision and burial of radioactive wastes (Ukraine, 1986-1997)	$1.3 million
Ramseger, Kalinowski, Weiβ (2009) – CBRN Threats and the Economic Analysis of Terrorism	Cleaning activities, decontamination and building of the sarcophagus, over 20,000 new houses, and 15,000 flats (Ukraine)	$17 billion
National Report of the Republic of Belarus (2011) – A Quarter of a Century after the Chernobyl Catastrophe: Outcomes and Prospects for the Mitigation of Consequences	Decontamination of contaminated areas (Belarus, 1986-2015)	$36.83 billion

Table 6: Costs Directly Related to Health

Source	Health Cost Description	Cost Amount
Voznyak (1996) – Report for the Russian Federation, *in: One Decade After Chernobyl: Summing up the Consequences of the Accident*	Public health protection and provision of specialized medical care (Russia, 1992-1995)	$17.8 million†
	Social and socio-psychological rehabilitation of the population (Russia, 1992-1995)	$2.2 million†
	Provision of medical care to children and pregnant women (Russia, 1992-1995)	$3.4 million†
	Medical and social support for disabled children in boarding schools (Russia, 1992-1995)	$1.3 million†
	Psychological support for children (Russia, 1992-1995)	$3.3 million†
Lych and Pateeva (1996) – Economic Effects of the Chernobyl Disaster: Estimation and Minimization Problems, *in: Ten Years After the Chernobyl Catastrophe*	Damage caused to people's health (Belarus, 1986-2015)	$1.9 billion
UNDP, UNICEF, UN-OCHA, WHO (2002) – Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery	Special medical care (Ukraine, 1992-2000)	$97 million
Bay and Oughton (2005) – Social and Economic Effects, *in: Chernobyl: Catastrophe and Consequences*	Special healthcare to affected population (Ukraine, 2000)	$6.4 million
National Report of Ukraine (2006) – 20 Years after Chornobyl Catastrophe: Future Outlook	Special medical help (Ukraine, 1986-1997)	$121.8 million
National Report of the Republic of Belarus (2011) – A Quarter of a Century after the Chernobyl Catastrophe: Outcomes and Prospects for the Mitigation of Consequences	Public health (Belarus, 1986-2015)	$93.27 billion

Cost figures provided in rubles were converted to US dollars by the following:

†Calculated using the average of rates at the end of the year for years 1992-1995 (2463 RUB = 1 USD).

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Appendix A: From 2013 Report – Specific Cost Estimates Related to the Disaster

Source	Estimated Amount	Targeted Countries	Notes
Chernobyl Forum (2006)	13 billion USD	Belarus	Costs by Belarus between 1991 and 2003
Institute of Economics of the Belarusian National Academy of Sciences (2001)	43.3 billion USD	Belarus	Economy of Belarus will suffer this amount of losses in the first 30 years
Institute of Economics of the Belarusian National Academy of Sciences (2001)	235 billion USD	Belarus	Total projected damage over first 30 years Ivan Kenik, Belarus's Chernobyl minister mentioned same estimates in interview in 2002. Also, many news articles use this estimate as well, including Forbes article.
World Bank – Belarus: Chernobyl Review (2002)	2.4 billion USD ["~20% of 2001 GDP"]	Belarus	Estimated resources spent on the mitigation of Chernobyl consequences between 1991 and 2001 Report does not attempt to calculate full costs of the disaster, but focus on current situation today.
World Bank – Belarus: Chernobyl Review (2002)	2.1 billion USD	Belarus	Projected costs for implementing social programs between 2001 and 2011 (stipulated by National Program 2001)
World Bank – Joint Country Portfolio Performance Review (2010)	80 million USD	Belarus	Loan given by World Bank (paid in 2006 and 2010) to "improving the livelihood" in Oblasts of Brest, Gomel, and Mogiliev
Ministry of the Russian Federation for Civil Defense Affairs (2001)	3.8 billion USD	Russia	Costs between 1992 and 1998 (of sum, 3 billion USD used as compensation to victims and helpers)
Chernobyl Interinform Agency (2002)	201 billion USD	Ukraine	Projected economic damage to Ukraine between 1986 and 2015
World Bank – Ukraine:	5.25 billion	Ukraine	Sum of estimated Chernobyl

Public Expenditure Review (1997)	USD		Fund spending between 1992 and 1996
European Bank for Reconstruction and Development	2.01 billion USD	Ukraine	Current estimated costs of the Shelter Implementation Plan (includes cost of New Safe Confinement)
Sherman & Yablokov (2011)	Exceeded 500 billion USD	Ukraine, Belarus, and Russia	Direct economic damage to Belarus, Ukraine and Russia Article in San Francisco Bay View but article rejected by The Bulletin of Atomic Scientists
Gorbachev interview in *The Battle of Chernobyl* (2006)	18 billion rubles	USSR	Amount spent in 1986 to contain the disaster and decontaminate the affected areas

Appendix B: Review of Reports on Estimates of the Economic Costs of Chernobyl Disaster

Below, we review estimates in publications identified through the search strategy enumerated in the section labeled **Methods** and listed in **Tables 4 and 5**. We provide all information available on the basis of the estimates; for some, only a citation to another report is available.

Anspaugh et al. (1988) – The Global Impact of the Chernobyl Reactor Accident

Referencing "Proceedings of the Scientific Conference on the Medical Aspects of the Chernobyl Accident," (Kiev, May 1988), the authors state that the total economic cost of the accident amounts to about $15 billion, including a direct cost of $6.8 billion (e.g., loss of the reactor, relocations, medical care, decontamination), an equal amount for indirect costs (e.g., replacement of lost power, new construction, food surveillance), and additional costs in other countries. Search of the mentioned source document did not find discussion of costs.

Steinhausler et al. (1988) – Chernobyl and its Radiological and Socio-economic Consequences for the Province of Salzburg, Austria

This is a very specific set of estimates, referenced to a particular time interval and the Province of Salzburg, Austria. Costs include direct damages (e.g., contaminated food destroyed) and indirect damages (e.g., involuntary price reductions due to reduced consumer demand, loss of market share) related to fallout contamination in Salzburg from May 1986-July 1987. Information was collected locally. Costs were calculated using a conversion rate of 1 US$ = 13 AS; the total was $5.647 M. Authors note challenges of assessing total costs due to unquantifiable factors such as reduced export.

Medvedev (1990) – The Legacy of Chernobyl

This book provides a comprehensive analysis of the global impact of the Chernobyl disaster. Overall cost estimates are provided, as well as specific compensation paid to farmers for losses in sales, restrictions on grazing, and countermeasures by governments of Hungary, Britain, Austria, and West Germany. Methods for how these estimates were calculated are not described.

Faure and Skogh (1992) – Compensation for Damages Caused by Nuclear Accidents: A Convention as Insurance

Written from an insurance perspective, this paper addresses appropriate compensation for losses resulting from nuclear accidents. In discussing costs of nuclear accidents, authors give a $15 billion estimate of direct losses in the Soviet Union due; however, no reference is provided for this estimate.

One Decade After Chernobyl: Summing up the Consequences of the Accident (1996) – Social, Economic, Institutional and Political Impacts (Background Paper 6)

This report, published one decade after the disaster, provides cost estimates related to the disaster for Russia, Belarus and Ukraine. The methods are poorly documented for each country and appear to vary across the countries. The separate reports for the countries follow:

- **Voznyak – Report for the Soviet Period:** "On the instructions of the USSR Government, the USSR Ministry of Finance published information provided by USSR ministries and departments and by the Councils of Ministers of the USSR, the Ukrainian SSR and the Byelorussian SSR." Total direct losses and outlays considered as relevant, but not necessarily estimated, included "losses of capital assets; production losses in agriculture and related sectors; actions to eliminate the consequences of the accident; the construction of homes, welfare facilities and roads; forest protection and water conservation measures; soil decontamination and treatment with lime; compensation to agricultural enterprises, co-operatives and the population at large for losses of crops, animals and possessions; removal costs; and payments of daily allowances to the population. They were covered: from the USSR budget and the budgets of individual Republics; through payments made by the State insurance company to individuals; agricultural enterprises and cooperatives; and from voluntary contributions of individuals and organizations."

- **Voznyak – Report for the Russian Federation:** The resources for mitigating the consequences of the accident are provided under three federal programs: Unified State programme on Protection of the people of the Russian Federation against the consequences of the Chernobyl disaster, Children of Chernobyl, and Housing for the Liquidators. The primary funding source is the federal budget, along with budgets of the Russian Federations constituent units, extra budgetary sources, and the Social Insurance Fund. The expenditures are divided into the following heads: current expenditures (practical measures), capital expenditure and payment of compensation and benefits.

- **Rolevich et al. – Report for Belarus:** Budgetary appropriations to deal with the consequences of the Chernobyl accident are in 5 main sectors (percentage of expenditure as of 1995): improving living conditions (58.7), resettlement (10.6), compensation (28), health care (2.0), and radiological monitoring (0.2). Scientists have calculated that the economic damage to Belarus from the accident is equal to 32 pre-accident annual budgets ($235 billion) over a 30-year recovery period. Until 1991, the Soviet Union financed the State program for mitigating consequences; however, in 1992, the responsibility was shifted entirely to Belarus.

- **Report for Ukraine:** Until 1991, the Soviet Union financed efforts to mitigate consequences of the Chernobyl accident; however, in September 1991, efforts were financed by the budget of Ukraine. The primary financing source was the LPA Fund, a special Fund for Measures to Eliminate the Consequences of the Chernobyl Disaster and Provide for Social Welfare of the Public, maintained by contributions from firms and commercial organizations. The proportion of the LPA Fund in the state budget ranged from 6.4% (1992) to 5.8% (1995).

Lych and Pateeva – Ten Years after the Chernobyl Catastrophe (1996) – Economic Effects of the Chernobyl Disaster: Estimation and Minimization Problems

This report describes four categories of costs: direct losses, indirect losses, lost profit, and additional expenditures. Total economic damage caused by the Chernobyl disaster during the period of 1986-2015 is calculated to be $235 billion, which amounts of 32 times the budget in 1985 or 21 times the budget in 1991. The majority of these costs (81.6%) were due to removal and minimization of the disaster aftermath; 12.6% were from direct and indirect losses, and 5.8% from lost profit. Information on how these calculations were made is not provided.

Tveten et al. (1998) – Economic Consequences of the Chernobyl Accident in Norway in the Decade 1986-1995

This paper gives economic costs specific to Norway for the period of ten years after the Chernobyl accident. Authors evaluate losses of particular products related to countermeasures and discarded foodstuffs, with total costs of mitigating actions amounting to $70 million. The cost figures described in this paper largely come from direct compensation paid to agricultural producers, as well as program costs for control and surveillance, research, planning, and administration.

Nisbet and Woodman (2000) – Options for the Management of Chernobyl-restricted Areas in England and Wales

This paper specifically discusses costs associated with sheep farming in western Britain due to the Chernobyl accident, including monitoring programs and compensation to framers.

UNDP, UNICEF, UN-OCHA, WHO (2002) – The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery

The report gives specific figures of Chernobyl budget expenditures in Ukraine, although no source is provided. While expenses for resettlement and living conditions has decreased over time, costs for social assistance (i.e., medical care, welfare payments, health holidays) has increased from 39% in 1992 to 87% in 2000. This report also contains general estimates of losses for Belarus and Ukraine provided by the Belarusian and Ukrainian governments. In Belarus and Ukraine, costs were covered through a Chernobyl emergency tax; in Russia, funds in the national and regional budgets largely provided the resources.

The Chernobyl Forum (2003-2005) – Chernobyl's Legacy: Health, Environmental, and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine

This report states, "various government estimates from the 1990s put the cost of the Chernobyl accident, over two decades, at hundreds of billions of dollars." The Ukrainian government spends 5%-7% on Chernobyl-related benefits and programs. Government spending on Chernobyl in Belarus during the period of 1991-2003 totaled over $13 billion, which amounted to 22.3% of the national budget in 1991 and 6.1% in 2002. No methodology for these estimates is provided.

Bay and Oughton (2005) – Chapter 7: Social and economic effects

This book chapter is a broad literature review of the economic impact of Chernobyl, citing cost estimates and expenditures from major government and agency reports.

National Report of Ukraine (2006) – 20 Years after Chornobyl Catastrophe: Future Outlook
"By the order of the government of the former USSR, the Ministry of Finance of the USSR analyzed the information of ministries and departments, branch departments of the Council of Ministers of the Union Republics of the USSR concerning the direct losses caused by the catastrophe at the Chornobyl NPP." Data on actual costs of measures to eliminate consequences of the accident and provided, calculated based on the total amount of direct expenses for the following categories: social protection of affected people, medical aid, research and development, radiation monitoring, ecological remediation of the environment, rehabilitation and disposal, capital investments, works within the Exclusion Zone, and other expenses. Certain indirect cost estimates are discussed, including contaminated agricultural lands, water, and forest resources, as well as the losses due to non-generated electric energy; however, it is noted that these estimates are not exhaustive.

Sovacool (2008) – The Costs of Failure: A Preliminary Assessment of Major Energy Accidents, 1907-2007
This paper gives a cost amount due to the Chernobyl disaster among a list of major global energy accidents from 1907-2007. No source or description of methods used to estimate costs is provided.

Ramseger et al. (2009) – CBRN Threats and the Economic Analysis of Terrorism
This report examines economic impacts of chemical, biological, radiological, and nuclear threats. While focusing on terror attacks, it includes the Chernobyl accident as an example of cost consequences for related incidents. Various cost estimates are given related to recovery, reconstruction, and restoration; indirect damage; and containment; the compilation of costs cite sources with no further description of methods.

National Report of Ukraine (2011) – Twenty-five Years after Chornobyl Accident: Safety for the Future
This report gives data on general costs provided by the Ministry of Finance of the USSR. While expenses are reported, methods are not described. Direct costs were determined from the total amount of financing for the following work on the direct elimination of the catastrophe in the exclusion zone, social protection of victims and the costs of corresponding medical programs, costs of implementation of scientific research programs, costs of the environmental radiation monitoring programs, costs of the decontamination work and handling of radioactive wastes. Certain indirect cost estimates are discussed, including contaminated agricultural lands, water, and forest resources, as well as the value of losses due to reduction of electrical energy production and related goods and services and how estimates were calculated. As noted in the report, information on other indirect losses to Ukraine's economy is not provided.

National Report of the Republic of Belarus (2011) – A Quarter of a Century after the Chernobyl Catastrophe: Outcomes and Prospects for the Mitigation of Consequences
This report gives economic damage estimates provided by the Institute of Economy of the National Academy of Sciences of Belarus. This estimate includes "losses related to the

deterioration of public health; damage caused to the industry and the social sphere, agriculture, construction sector, transport and communication, community facilities; contamination of mineral, raw, land, water, forest and other resources; as well as additional costs of the measures for the cleanup and minimization of the effects of the catastrophe and providing a safe living environment for the population." Damage costs by sector are also provided, but methods are not described.

Hogberg (2013) – Root Causes and Impacts of Severe Accidents at Large Nuclear Power Plants
This paper discusses the causes and impacts of three nuclear power plant accidents, including the Chernobyl disaster. It briefly mentions the socioeconomic impact of the Chernobyl, giving a broad estimate of total costs. No source or description of methods used to estimate costs is provided.

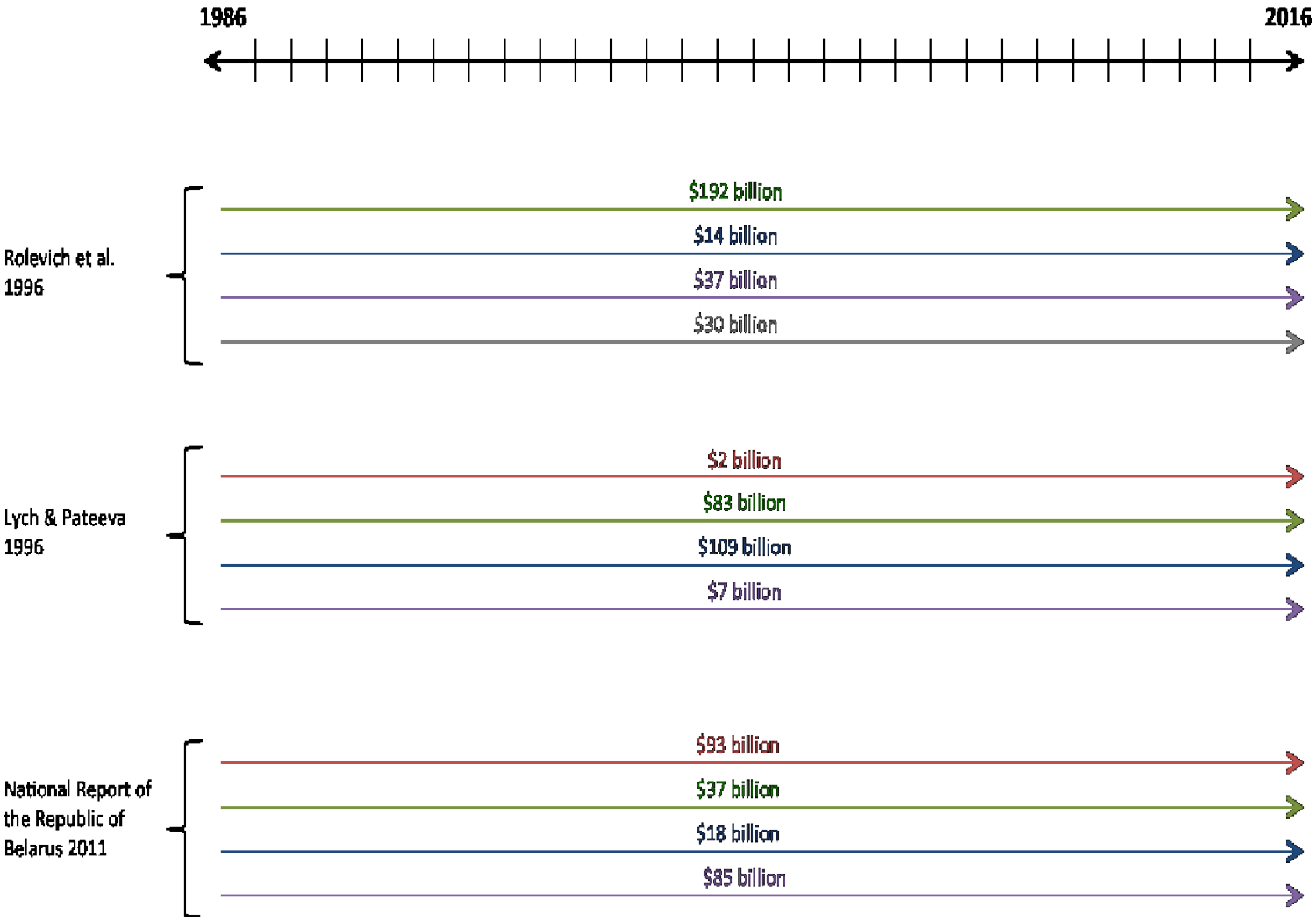
Appendix C: Timeline of Cost Estimates and Expenditures in the Literature by Country

LEGEND:

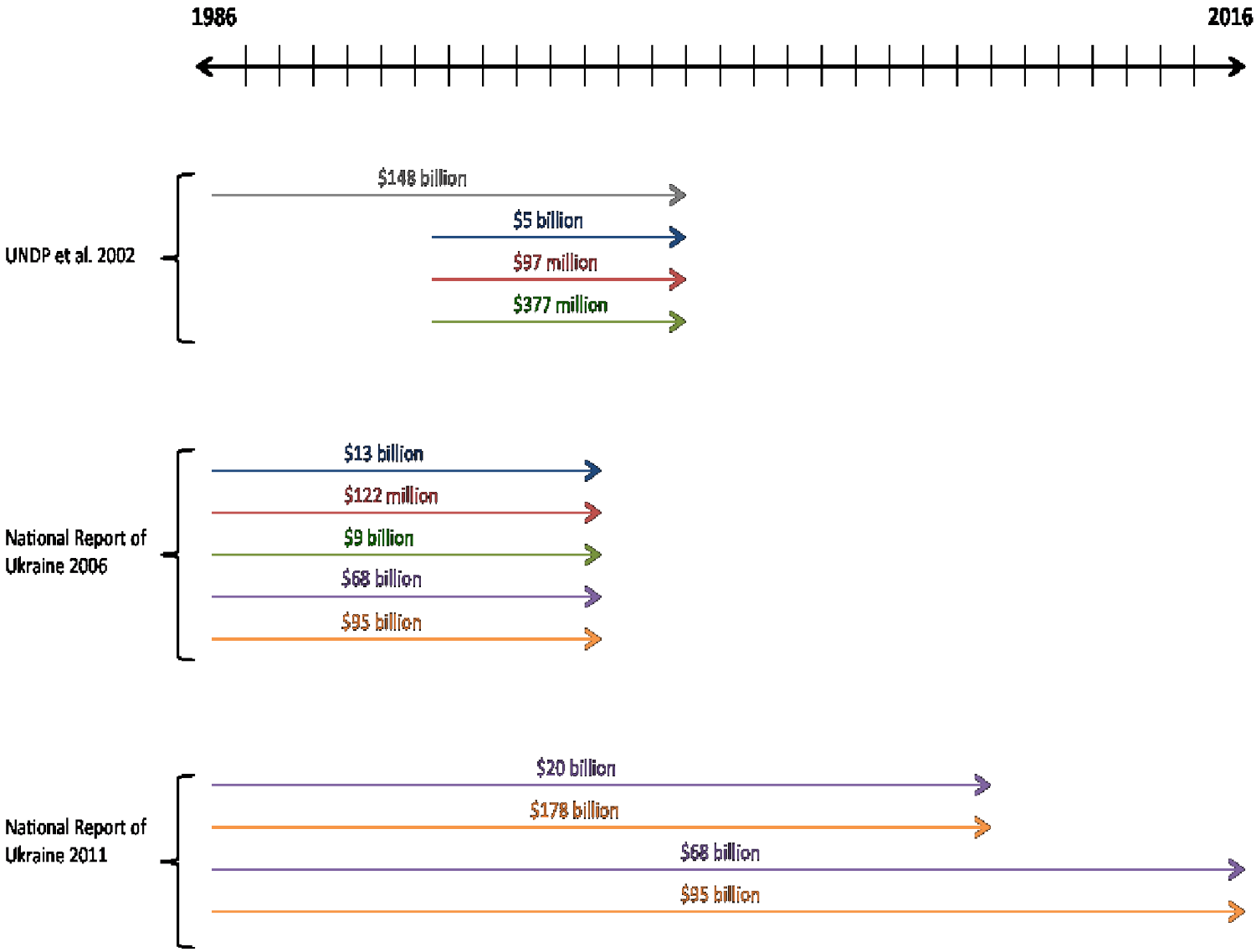
Arrow Color	Cost Category
	Plant Costs (i.e., decontamination, radiation control, maintenance/work in exclusion zone, radioactive material disposal)
	Social Costs (i.e., social protection, programs and support, compensation, housing/resettlement)
	Health Costs (i.e., medical care, public health protection, psychological care)
	Industry/Agriculture Costs (i.e., misuse of land, agriculture, forest, farming, other industries and economic sectors)
	Lost Energy Costs (i.e., value of lost energy production, losses due to closure of existing nuclear power plant)
	Unspecified Losses

*Note: costs are rounded to nearest dollar

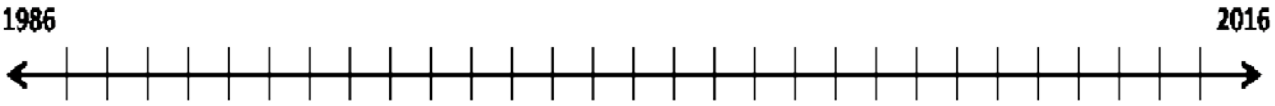
TIMELINE FOR BELARUS:



TIMELINE FOR UKRAINE:



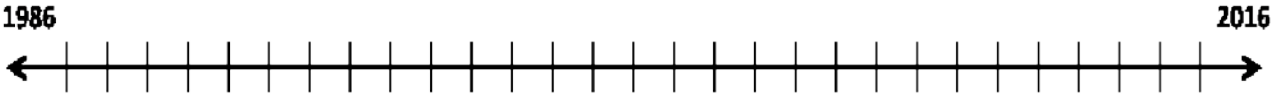
TIMELINE FOR RUSSIA:



Voznyak 1996

- $754 million
- $28 million
- $12.9 million
- $0.17 million

TIMELINE FOR OTHER COUNTRIES:



National Report of Ukraine 2006; National Report of Ukraine 2011 — $12.6 billion (Soviet Union)

Steinhausler et al. 1988 — $5.6 million (Austria)

Tveten et al. 1998 — $70 million (Norway)