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**A Whole Wilderness of Warning: Assessing Economic Consequences of Nuclear Releases –
15494**

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ABSTRACT

The consequences of the Fukushima Dai-ichi disaster may provide a useful analogue for assessing the consequences of an accident involving the transport of spent nuclear fuel in the United States. An unexamined, to date, aspect of the Fukushima Dai-ichi disaster is the wide disagreement about the economic consequences of the release. There exist a variety of different estimates and different models and methods for performing these estimates, but not a systematic way to address the range of issues such a disaster generated. This paper examines the sources, methods, data, and assumptions used to prepare economic consequence estimates of the disaster. This paper compares and contrasts these estimates and evaluates them for their reliability. The wide dispersion of consequence assessments as defined by various media and agency impact reports in the post-Fukushima era are evidence that such variability does not serve the industry, regulators, government or researchers well. While a protocol exists to gauge the intensity of an incident (INES Scale) no pre-existing methodology exists to measure the various socioeconomic impacts associated with a radiological disaster, be it induced by a natural disaster incident or human initiated. This paper argues that an improved method will be necessary and suggests some parameters for such a method.

Nevada has started the dialogue on such a comprehensive methodology (Ballard 2012, Ballard 2014). Despite this effort by a stakeholder, the regulatory agencies involved in nuclear waste shipments in the United States appear reluctant to begin a dialogue about how to address the full range and scope of issues. Resolution of this problem will be a necessary prerequisite to any large scale shipping program. It will be necessary to adopt a standardized methodology to assess consequences of a radiological emergency and incorporate this into the environmental impact statement process for the shipping program. This analytical deficiency should be addressed by these agencies/regulators and in preparation for the potential movement of nuclear waste in the

quantities necessary to service the nuclear power industry and to address the existing spent nuclear fuel (SNF) stockpiles across the United States. It will be necessary to demonstrate to stakeholders that the benefits of shipping radioactive substances this dangerous outweigh the costs of a possible accident or terrorist incident.

The nuclear energy industry should support funding for these assessment studies in order to provide a basis for discussions about the costs and benefits of the shipments. The studies would provide stakeholders with clarity about the possible consequences of the program. The studies will also assist Japan in its efforts to understand what their disaster means for that country. This paper will begin the dialogue on how such analytical protocols could be constructed to pre-stage the research necessary to assess such consequences.

INTRODUCTION

The impact of the Fukushima Dai-ichi disaster can be measured in many ways. While a protocol exists to gauge the intensity of an incident (INES Scale) no pre-existing methodology exists to measure the socioeconomic impacts associated with a radiological disaster. Nevada has started the dialogue about the development of a method (Ballard 2012).¹ Despite this initial stakeholder effort, the primary oversight agencies involved in nuclear waste shipments (DOE/NRC) have not addressed the range and scope of issues to assess consequences of a radiological emergency. This analytical deficiency should be addressed by these agencies and in preparation for the potential movement of nuclear waste.

This paper reviews the literature related to the consequences of the Japanese disaster. It does this through the lens of the State of Nevada's legal contentions regarding shipments of SNF. These contentions are associated with Nevada's case in the Yucca Mountain licensing proceeding.

Underlying this presentation is the assumptions that in the event of an incident involving SNF, there will be long-term, massively disruptive consequences. These consequences will be radiological, social, economic, political, and legal in nature. These categories of risks have occurred and continue to endure in Japan in the aftermath of that disaster. This paper examines the past media/agency assessments of that disaster and shows that there is a wide variability in the estimates.

To summarize the findings of this study, the non-radiological consequences of the Fukushima Dai-ichi disaster suggest the current means to estimate the consequences of a radiological disaster severely underestimate the cost of recovery. The United States implications of this finding are:

- The Price-Anderson Act is insufficient to cover the costs of an incident and the burden will be on the taxpayer to cover the billions, tens of billions and/or hundreds of billions,

¹Ballard, J. D. (2012). "Japan's Fukushima Daiichi Disaster: Implications for Further Research on Terrorism and Sabotage." *Nuclear Waste Project Office*, State of Nevada.

in economic losses that result from an act of terrorism, sabotage or other human initiated event involving SNF and/or high level radioactive wastes (HLW).

- The Price-Anderson Act is insufficient to cover the costs of an accident involving SNF/HLW and likewise the financial burden will be on the American taxpayer to cover the economic losses that result.
- Agencies with regulatory and operational authority (NRC/DOE) should pre-determine a research protocol from which such costs could be assessed and field test such a methodology on other incidents in preparation of a potential radiological emergency (terrorist act or accident) that could transpire during transport of SNF/HLW. Part of that effort would be to address the shortcomings in Price-Anderson liability coverage and advocate for its updating to properly address the costs such a study protocol would reveal.
- The lack of attention to this problem may enhance the liability of industry in the post-incident social environment. Knowledge of the true scope of post incident cost impacts is now emerging and failure to plan for such impacts may show a lack of prudent planning and thus increase corporate, individual and agency responsibility in the event of an incident.

BASIS FOR ANALYSIS

This report's analysis uses a review of the four NEPA contentions put forth by Nevada in the licensing proceedings. The contentions relative to this analysis are as follows:

1. NEV-NEPA-01 - TRANSPORTATION SABOTAGE SCENARIOS

“Final Supplemental Environmental Impact Statement for Yucca Mountain, DOE/EIS 0250S-F1 (07/2008) (“FSEIS”) Subsection 6.3.4.2 and Appendix G.8, regarding transportation sabotage events, fail to evaluate reasonably foreseeable attack scenarios that could result in significantly greater consequences than the scenarios considered by DOE. This deficiency is significant because, without considering reasonably foreseeable attack scenarios, there is no adequate disclosure of environmental impacts under NEPA. If reasonably foreseeable attack scenarios were added, the disclosure of radiological impacts could be materially different, thus the FEIS and FSEIS cannot be adopted by the NRC.” (p. 1043).

2. NEV-NEPA-02 - TRANSPORTATION SABOTAGE CLEANUP COSTS

“Final Supplemental Environmental Impact Statement for Yucca Mountain, DOE/EIS 0250S-F1 (07/2008) (“FSEIS”) Subsection 6.3.4.2 and Appendix G.8 regarding transportation sabotage events, and FSEIS Appendix G.9.7 regarding cost of cleanup after accidents, fail to provide an estimate of the cost of cleanup and other economic impacts following a sabotage event that resulted in release of radioactive materials, even though DOE assumes that cleanup would occur. This deficiency is significant because, without considering the cleanup costs of reasonably foreseeable attack scenarios, there is no adequate disclosure of environmental impacts under NEPA. If the cleanup costs of

reasonably foreseeable attack scenarios were added, the disclosure of radiological impacts could be materially different, thus the FEIS and FSEIS cannot be adopted by the NRC.” (p. 1048).

3. NEV-NEPA-03 - TRANSPORTATION ACCIDENT CLEANUP COSTS

“Final Supplemental Environmental Impact Statement for Yucca Mountain, DOE/EIS 0250S-F1 (07/2008) ("FSEIS") Appendix G.9.7, regarding the cost of cleanup from transportation accidents, fails to provide verifiable estimates of the costs of cleanup following severe transportation accidents that resulted in release of radioactive materials. This deficiency is significant because, without considering reasonably foreseeable transportation accidents and their effects including cleanup costs, there is no adequate disclosure of environmental impacts under NEPA. If reasonably foreseeable transportation accidents and their effects including cleanup costs were properly considered, the disclosure of radiological impacts could be materially different, thus the FEIS and FSEIS cannot be adopted by the NRC.” (p. 1052).

4. NEV-NEPA-05 - RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION

“Final Supplemental Environmental Impact Statement for Yucca Mountain, DOE/EIS 0250S-F1 (07/2008) ("FSEIS") Subsections 3.2.2 and 6.4.1, and Final Environmental Impact Statement for a Rail Alignment, DOE/EIS 0369 (06/2008) ("Rail Alignment FEIS" or "RA FEIS") (incorporated by reference in the FSEIS at 6-1) Subsection 3.2.10, which address the radiological regions of influence for transportation, fail to apply the preferred method of analysis consistently for transportation impacts in Nevada and nationally. This failure is significant because without consistently evaluating the radiological regions of influence for transportation DOE has failed to adequately assess their environmental impacts, and because those environmental impacts could be materially different from that presented in the FSEIS and the RA FEIS, neither document can be adopted by the NRC.” (p. 1061).

STANDARDIZING ANALYSIS

To more effectively use these four Nevada contentions in the analysis of the variety of socioeconomic impacts identified as a result of the Fukushima Dai-ichi disaster, each sub-section below will use the following matrix to concisely address the issues. This matrix and the observations contained therein represent a form of methodological executive summary for each of the topic areas covered – radiological, social, economic, political, legal costs and so on. As such each should be read and understood as a sub-section analysis relative to that specific category as found in the literature. The generalized format of the report will be:

Nevada NEPA Contentions	Connections to the results of Fukushima Dai-ichi	Additional Contentions Arising?
#1: TRANSPORTATION SABOTAGE SCENARIOS		
#2: TRANSPORTATION SABOTAGE CLEANUP COSTS		
#3: TRANSPORTATION ACCIDENT CLEANUP COSTS		
#5: RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION		

SOCIAL IMPACTS

After qualitative analysis of the literature on the social impacts associated with Fukushima Dai-ichi, the connections to the four Nevada contentions based on the literature can be summarized as follows.

Nevada NEPA Contentions	Connections to the results of Fukushima Dai-ichi	Additional Contentions Arising?
#1: TRANSPORTATION SABOTAGE SCENARIOS	Other than one study linking terrorism to the Fukushima Dai-ichi disaster, the discussions in this section do not necessarily offer any additional insight into sabotage scenarios. The sum total of the social scan of literature shows the impacts of sabotage are far more than just radiological or economic. For example: The social dislocation resulting from this disaster was evidence of this	Perhaps not news, the idea of social impacts is foundational to this analysis and as such existing means to assess impacts of a radiological accident are not a reasonable measure of these impacts considering how profound and long term the impacts may become. A contention that asks NRC to consider the micro and macro impacts of a disaster, in terms of time (short term, moderate term and long term) is not

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	assertion.	unreasonable. Some topics that could be included in a social analysis of the impacts would be the legacy effects of such a disaster (stigma being one such impact), the backlash/social protest movement that such a disaster can create, the social dislocation of citizens and foreign nationals, social panic and impacts of such areas of study as population dynamics.
#2: TRANSPORTATION SABOTAGE CLEANUP COSTS	In a similar way to the way media and agencies focus on clean-up costs – misses the point that the costs of recovery are far more than just the costs of radiological remediation. Agencies like the NRC and DOE should consider the overall social recovery necessary to offset the disruption to society such an event creates.	Included above.
#3: TRANSPORTATION ACCIDENT CLEANUP COSTS	Costs are far greater then considering the totality of radiological effects alone – social costs like increased suicide and legacy effects - like lowering birth rates - on societies are not easy to measure but do call for the development of a standardized protocol for the assessment of all risks, consequences and social impacts related to a large scale radiological disaster.	Included above.
#5: RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION	This area of the literature review says little to connect to this contention.	Not readily applicable other than the stigma effects discussed above.

ECONOMIC IMPACTS

After qualitative analysis of the literature on the economic impacts associated with Fukushima Dai-ichi, the connections to the four Nevada contentions based on the literature on economic impacts can be summarized as follows.

Nevada NEPA Contentions	Connections to the results of Fukushima Dai-ichi	Additional Contentions Arising?
#1: TRANSPORTATION SABOTAGE SCENARIOS	Using a range of scenarios would allow the DOE/NRC to better plan for the economic consequence of a disaster that is human initiated. The economic losses arising from the Japanese disaster and how the estimates of losses vary are evidence that having a range of consequence possibilities in the analysis is reasonable and prudent. The varying degrees of impact can at least estimate more accurately the possible consequences of a radiological event.	Nevada has long pressed for the use of a range of scenarios and more realistic scenarios by these agencies. Such an argument is critical and should be enhanced by the events in Japan. Information on the economic losses could help bolster existing contentions.
#2: TRANSPORTATION SABOTAGE CLEANUP COSTS	The economic consequences of the Japanese disaster were profound and not necessarily easily quantifiable. Some observers quickly noted how this disaster offered a chance to “reform” the economic system while not addressing the very real issues confronting the government in addressing the environmental, social, political and economic disaster faced by the nation of Japan. Such predatory analysis will be present in the aftermath of a	Again a standardized protocol for assessing impacts and consequences, in place prior to an incident, could help in addressing the issues. This may be an additional contention for Nevada – namely that the DOE/NRC has not set up such an assessment and needs to for stakeholder confidence to be increased. A USC analysis of the impact of a radiological incident in the Port of Los Angeles showed widespread local, national and international impacts – such

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	<p>radiological attack – some will focus on how business can help in the cleanup and how that effort will enhance the bottom line of some companies. Others will use the incident to justify closure of all nuclear plants.</p> <p>This distraction narrative would be countered by a standardized protocol to measure the effects – both positive and negative - of a radiological disaster. Without admission of the fact that impacts will exist and without a protocol to address how these should be measured, the NRC/DOE agencies responsible for the aftermath of a disaster will be equally at the whim of ideological observations that do not address the real impacts and risks.</p>	<p>a predictive model could be adapted and/or developed to address a SNF incident and based on different locations – rural, suburban and urban. The social science methodology is available, the will of the agencies to address these variables – perhaps not so willingly available.</p>
<p>#3: TRANSPORTATION ACCIDENT CLEANUP COSTS</p>	<p>Similar arguments for accidents as for human initiated events.</p>	<p>Similar arguments for accidents as for human initiated events.</p>
<p>#5: RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION</p>	<p>The spread and impacts on the economics of America must be understood in terms of its global economic leadership position. As the leading economy in the world (as of this year), any radiological based disruption to the American economy will impact exports as other countries question the viability of the products being sold.</p>	<p>Nevada might consider making an economic impact argument that addresses the loss of business as a result of any radiological contamination event. The “mad cow” disease economic impacts are an example that may assist in such an argument. Here, meat producers from across the country were impacted because of an isolated few cases.</p>

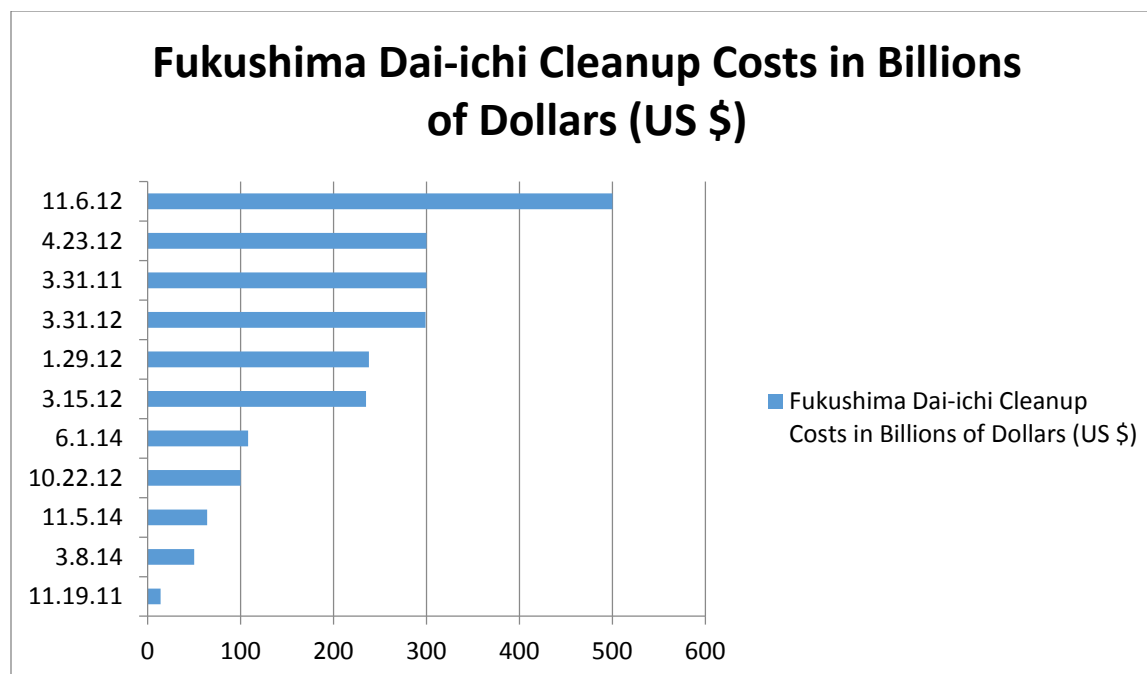
ECONOMIC IMPACTS CONTINUED

In addition to the qualitative analysis of the literature, a data visualization analysis was conducted. The results of this analysis were graphed and shown below. The results of these exemplar cost estimates indicate the range of reported impacts across the world. In many cases these numbers were repeated, echo chambered, by various media outlets – the World Bank number being a good example.

The wide range of estimates may be because of differing ways to articulate what is being measured – some reports focused on cleanup costs for SNF, others on the costs for the disaster site, some included the overall community impacts including business losses and finally, perhaps a larger number that account for the loss of business, recovery and compensation costs. None of the reports use a standardized methodology to assess the costs and thus, the estimates depend on the purpose of the media report, the reporting organization mission and/or the agency and its agenda.

One example of how agency mission may effect reporting is that of the IAEA, which has many reports on the accident, evaluation of these reports shows most of the verbiage does not address the costs, rather it looks at the regulatory failures of the government/utility and what is needed for reform. The same is true of the NRC and World Nuclear Association – lots of reports, including Congressional testimony in the case of NRC, but not necessarily estimates on the totality of the social economic costs and few/no discussions on methods to assess them.

As noted in several places in this report Nevada may consider asking, or even as a new contention, demand the creation of a standardized methodology to assess these types of nuclear incident costs. The need is clear given the imprecision of the estimates and the reasonable questions a social scientist would ask regarding validity and reliability of such estimates.



POLITICAL IMPACTS

After qualitative analysis of the literature on the political impacts associated with Fukushima Dai-ichi, the connections to the four Nevada contentions based on the literature on political impacts can be summarized as follows.

Nevada NEPA Contentions	Connections to the results of Fukushima Dai-ichi	Additional Contentions Arising?
#1: TRANSPORTATION SABOTAGE SCENARIOS	The range of scenarios in Nevada’s work to date show that the state has at least considered the issues associated with an attack. The limited scope of those scenarios does not allow them to include political consequences, but those impacts should be obvious to observers. The key issue seems to be liability – does the Price Anderson Act suffice and how do its limits on liability protect the energy industry but perhaps leave local, state and tribal	Nevada could consider filing a contention on the failure of DOE/NRC to address liability and the need for them to do so. This would establish the precedent for future liability claims. After this filing a campaign of education of leaders on both sides of the isle and reminders of their responsibilities may be a possible way to pressure these agencies to do their work more correctly and to stop avoiding the issues brought forth by Nevada.

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	governments on the hook for unfunded liabilities like emergency response?	
#2: TRANSPORTATION SABOTAGE CLEANUP COSTS	<p>The political fallout of a successful attack, or even an attempt, on these shipments would be serious. In Japan, the government fell mainly because of the failure to tell the public the truth about the accident and the aftermath. Avoidance of the issues, obscuring the reality of the radiological consequences and avoiding the preparations necessary to at least have the information available for dissemination to the public, were several of the political lessons learned from Japan. Given the lack of will by DOE/NRC to admit to any socioeconomic risks, to face the need to measure those risks and to preplan to measure the consequences will insure serious political consequences for those in political power as well as those who run these agencies. After decades of notice by Nevada of the potential fallout from a successful attack, the liability for such negligence will be enormous.</p>	<p>In the Japanese crisis the costs of the disaster were intermingled with those of the natural disasters that occurred. The same intermingling of costs can be expected in a human initiated event or accident. Such collateral damage would be important to predict in the planning of either. As part of a new contention(s) Nevada may consider how best to construct that assessment and how it could be fixed into any methodological approach to various transportation incident scenarios.</p>
#3: TRANSPORTATION ACCIDENT CLEANUP COSTS	See above.	See above.
#5: RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION	Not necessarily applicable.	Not necessarily applicable.

LEGAL IMPLICATIONS

After qualitative analysis of the literature on the legal impacts associated with Fukushima Dai-ichi, the connections to the four Nevada contentions based on the literature on legal impacts can be summarized as follows.

Nevada NEPA Contentions	Connections to the results of Fukushima Dai-ichi	Additional Contentions Arising?
#1: TRANSPORTATION SABOTAGE SCENARIOS	The accident and natural disasters in Japan point out the limits of liability coverage and the potential for litigation against companies that are involved in the transportation effort for SNF and HLW. Given the experiences in Japan and the estimates of costs for the impacts, the Price-Anderson Act is insufficient to address the costs of a radiological incident and those agencies that regulate the title and movement of these materials will need to have governmental approval for the additional funding necessary to address an incident. Given current political trends, such funding is uncertain. Additionally, given the trends seen from the Japanese experience and with the state of the legal infrastructure in America, those companies that are involved in building containers, transporting and/or supervising these shipments may be held liable given the pre-knowledge of the limits of Price-Anderson.	Nevada should consider addressing the Price-Anderson issue in contentions. Specifically, the lack of certainty results in, or could result in, an unfunded mandate to state and local governments to cover costs for an incident involving these radioactive materials. This is beyond the argument that Price-Anderson is insufficient, rather it gets to the legal argument that these agencies and the federal government had prior knowledge of this shortfall and allowed these programs to go forward despite such risks. Such pre-knowledge would be tantamount to negligence on the part of those involved, industry, transportation companies, insurers and government. In legal proceedings such negligence and fore-knowledge may mitigate limits on liability. Legal counsel for the state may need to address such issues and in venues outside of the proceedings.
#2: TRANSPORTATION	In a similar manner, the	A similar argument could be

<p>SABOTAGE CLEANUP COSTS</p>	<p>clean-up costs will become a legal point of contention as claimants seek to recover costs of losses. These losses can include disruptions to supply chains as happened in Japan, but also stigma costs for lost real estate values, losses in normal business operations, and many other creative ways the legal profession will seek to address those losses.</p>	<p>made here.</p>
<p>#3: TRANSPORTATION ACCIDENT CLEANUP COSTS</p>	<p>The accident costs would be similar to those from a human initiated event and thus similar legal liabilities should be considered.</p>	<p>A similar argument could be made here.</p>
<p>#5: RADIOLOGICAL REGIONS OF INFLUENCE FOR TRANSPORTATION</p>	<p>Given the expected mass social hysteria resulting from a radiological emergency, the legal profession may well argue that the influences of a disaster range far wider than the initial zone of exclusion.</p> <p>Likewise the prior knowledge of the industry, individual business entities and regulatory agencies of the insufficient coverage of Price-Anderson most likely will increase awards in the event of inevitable and potentially successful litigation.</p>	<p>A similar argument could be made here.</p>

CONCLUSION

This analysis used the contentions provided by Nevada to format the ways to look at the various categories of social economic impacts from a radiological disaster. Nevada has consistently led the discussion on impacts or transporting highly radioactive materials like SNF and HLW. Herein, the arguments suggested further ways Nevada could argue that what happened in Japan

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was a predictor for what will happen after an accident or terrorist attack against shipments in the United States. The impacts are multi-faceted, multi-variable and multi-dimensional. Existing ways to measure such impacts are insufficient and with the state of knowledge that exists after Fukushima Dai-ichi, the agencies, regulators and business associated with the production and transportation of such materials – all should reconsider their liability profile. Ignorance is not bliss in this case – claims of not knowing what impacts are predictable is equally as bankrupt of a strategy. The facts are clear – these entities have fore knowledge and any incident, be it an accident or human initiated event, the liability for the aftereffects will not be covered by the Price Anderson Act nor will claims not to know the extent of what will happen. In the aftermath of the disaster in Japan, these agencies, regulators and the energy infrastructure must address these issues. The ideas herein, namely that the various categories of risks are relevant, these ideas need to be addressed and addressed sooner rather than never.

METHODOLOGY

This report is a compilation of publicly available materials that were synthesized into the analysis above. The open source analysis process herein began with defining the search terms and potential media outlets that covered the Fukushima Dai-ichi disaster. The search terms and locations are as follows:

Websites:

CNN
Greenpeace
IAEA
Safecast.org
World Health Organization (WHO)
NEI
Wikipedia
TEPCO
Groupe Intra
Landysh
NOTAM
National Institute of radiological Sciences
Federation of Electrical Power Companies (Japan)
Japan's Science and technology Agency
Japan's Atomic Energy Commission
Safety Policy Unit of the OK National Nuclear Corporation
Spiegel On-line
NISA
SPEEDI
International Commission for Radiological Protection
Research Institute for radiation, Biology and Medicine
Red Cross
International Business Times

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Bulletin of the Atomic Scientists
Australian Network News
World Scientific
Euro news
BBC News
Reuters
CS Monitor
Bloomberg
Japan Times
Mainichi Daily News
USA Today
Science Magazine
Nature Magazine
Breakbulk

Radiological Issues:

Iodine 131 (I^{131})
Cesium 137 (CS^{137})
Japan-Ukraine connections (Chernobyl)
New limits of life span (radiation does)
Japan's Ministry of the Environment

Social Impacts:

Families
Hospitals
Doctors
University attendance/enrollment
Resorts
Orchards
Fishing
Vegetables
Farming
Rice
US Military responses and evacuation

Economic Impacts:

Economic impacts of the disaster
Ripple effects
Economic bounce
Reconstruction bounce
Trade deficit
GNP/GDP
Inflation/deflation
Private sector recovery
Public sector recovery

Political Impacts:

Government of unity
Conservatives
Radical restructuring of government
NGO's responding to Japan
Public confidence
SAGA District Court
Fukushima District Public Prosecutors
Japan's Renewable Energy Foundation

Legal Issues:

Price-Anderson Act (in the US)
Japanese Corporation Laws
Oversight of Japanese nuclear industry
Japan Atomic Energy Insurance Pool
Nuclear Damage Liability Facilitation Fund
Dispute Reconciliation for Nuclear Damage

Terminology:

Urgent Protection Action Planning Zones (UPZ)
Debris disposal (rail, barge, ship, truck...)
MOX in reactors
NPP
Nuclear Information gap

Places:

Hamaoka Nuclear Power Plant
Chubu Electric Power Company
Kansai Electronic Power Company.
Monju fast-breeder
Nagasaki/Hiroshima