Considering Environmental Health Risks of Energy Options: Hydraulic Fracturing and Nuclear Power

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1. Introduction

Increased public concerns about the global impacts of climate change have heightened interest in reliable energy sources that reduce greenhouse gas (GHG) emissions. Greater awareness of the impact of these emissions on climate change has led to coal-fired power plants being phased out in many areas of the world, including in the United States. At the same time, new plants are being developed in other areas (including China), as are plans for more nuclear power plants [1]. Recent projections for the U.S. suggest that natural gas will surpass coal as the largest component of electricity generation over the next twenty years, accounting for more than a third of the total by 2035. The share of electricity generated by nuclear power plants is anticipated to increase by 5% by 2040. In comparison, renewable energy sources other than hydropower are projected to comprise 28% of the overall growth in electricity generation during this same period [2].

With conventional fossil fuel sources identified as dominant contributors to the GHG problem, the push for alternatives including renewable energy systems has been strong. Recent technology developments such as advanced optical materials and feathered turbine blades that accommodate a wider range of wind speeds have improved lifecycle estimates for variable renewables like solar and wind energy, respectively. Nevertheless, traditional sources such as nuclear fuel and oil and natural gas continue to be regarded as primary anchors while alternative energy sources are developed, or as transition or bridge sources toward ultimately establishing a sustainable set of energy options. With a focus on environmental health issues, two options that engender substantial public concern are: (1) nuclear power plants, and (2) unconventional oil and gas development and production, notably hydraulic fracturing. Opportunities for information and communication technologies (ICT) to promote targeted information sharing and facilitate citizen science initiatives are increasing, toward improving the understanding of specific environmental implications of energy options. A key goal is to more broadly inform the development of sustainable energy programs.

2. Environmental releases and health risk concerns

Different environmental pollutants are associated with nuclear power plant operations and hydraulic fracturing activities. Illustrative issues that have been raised for each are highlighted below.

For nuclear power plants, radioactive releases are a primary concern. Liquid effluents are routinely discharged as part of normal operations, with the amount of radioactivity depending on the type of reactor. For example, pressurized water reactors typically release more tritium than boiling water reactors, by a factor of 20 or higher [3]. In the event of an accident at a nuclear power plant, airborne releases are the key concern, with potential for widespread dispersion and deposition. The scale of contamination is well illustrated by the recent Fukushima disaster. Cancer morbidity and mortality represent primary health concerns for exposure to ionizing radiation; potential noncancer endpoints such as cardiovascular effects have also gained attention more recently [4]. Potential

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Effects associated with atmospheric releases and proximity to nuclear facilities has been reported by Scherb and Voigt [5, 6] using sex odds at birth as a proxy in the absence of actual exposure data (which would be important to determining such a link; see related note from McKenzie et al. [7] below regarding the need for exposure data to explore associations indicated by a proxy).

For hydraulic fracturing, chemical pollutants are a primary concern; naturally occurring radioactive material (NORM) and technologically-enhanced NORM (TENORM) also represent public concerns. In some cases, unconventional gas development is occurring in regions where uranium has been mined and milled, with a history of exposure and risk concerns regarding natural radionuclides such as radium (as highlighted in a recent review by [8]. Such natural radioactivity is also of concern for wastewaters from hydraulic fracturing.

Considering impacts to water quality, five different sources of contaminant releases have been identified: (1) spills during transportation of fracking fluid and produced water; (2) leaks from casings of production wells; (3) leaks through fractured rock in the affected zone; (4) discharges from the drilling site; and (5) wastewater disposal [9]. The latter has been identified as the driving concern for water contamination, posing a threat estimated to be thousands of times higher than from the other pathways [10].

In a recent review, Vengosh et al. [11] report evidence of effects in areas of intensive shale gas development that include stray gas contamination and surface water impacts. Various waste management approaches are being evaluated to reduce levels of dissolved pollutants released to water, such as a recent study that blends flowback fluid with acid mine drainage effluent to precipitate solids for subsequent removal [12].

One of the reasons for heightened public concern about impacts to water – notably drinking water sources – stems from the lack of public information about all the chemicals involved in the fracking process, including proprietary proppants. A recent study reports that natural gas drilling operations increased the activity of estrogen-disrupting chemicals in local surface water and groundwater [13].

In considering the potential for chemicals released by natural gas development activities to include teratogens, McKenzie et al. [7] conducted a retrospective cohort study of birth outcomes in rural Colorado using distance to maternal residence as an estimator of possible exposure. The authors reported a negative association with preterm birth, a positive association with fetal growth (the magnitude of association was small), and no association with oral clefts. From this initial evaluation, the authors observed an association between density and proximity of natural gas wells within a 10-mile (16-kilometer) radius and prevalence of congenital heart defects and possibly neural tube defects. The authors importantly qualify these observations with the statement that specific exposure estimates are needed to further explore the associations.

Although some chemical data are available via a clearinghouse website (see the discussion of FracFocus in Section 4), a substantial amount of data are not. Beyond the chemical content, associated contaminants of proppants and other materials that are being imported for use in well development and production are also concerns. It is difficult for agencies and citizens to assess the need for exposure controls to limit health risks when the nature of those potential exposures is unknown.

Airborne releases associated with hydraulic fracturing are also a substantial concern, with particulate matter and methane being among the pollutants of interest. The type of fracturing affects the extent of releases, with the volume of water needed having a marked influence. For example, to support recent evaluations by the U.S. Environmental Protection Agency [15], the transport of water needed for coal-bed methane extraction was estimated at 16 to 115 trucks per well fracture event, compared to about 1,660 trucks needed for shale gas extraction [14]. Thus, diesel particulate
matter (DPM) emissions are substantially higher for shale gas extraction, and these highly respirable particulates have been identified as a key public health concern, with effects ranging from lung cancer and asthma to heart disease [16].

Another health concern related to air quality effects involves frac sand, due to substantial releases associated with mining, transport, and staging for use in fracking operations. In response, some states are pushing to develop air quality standards for these crystalline silica particulates to help assure health protection, including the State of Minnesota. Key health concerns include respiratory and cardiovascular diseases [17].

Fugitive methane also poses a substantial air quality concern, although it is not typically a health risk issue. These significant threat posed by these fugitive emissions is to climate change; methane is a highly potent GHG, readily transforming to ozone in the atmosphere. The scale of these releases is illustrated in the following example for a U.S. shale gas development area of Texas. During a July period, it was estimated that more than more than 270 tonnes (300 tons) of fugitive methane was released each day by hydraulic fracturing activities in the Dallas-Fort Worth area, mostly from the condensate and oil tanks at the well sites. This amount generated by oil and gas extraction activities was estimated to account for more tropospheric ozone in that area than the entire fleet of cars, trucks, and other mobile sources combined [18].

3. Citizen science: monitoring initiatives

Environmental monitoring programs are commonly constrained by competing demands for limited resources. ICT advances have made it possible for citizen scientists to help fill in some of the resulting gaps in environmental characterization, as community-based initiatives are providing alternate means for collecting and combining data from the local to the regional scale and beyond.

For example, following the Fukushima disaster, it was difficult for Japanese citizens to find information about environmental radiation levels, not only in the immediate area of the failed nuclear reactors but also for areas in which many lived and to which others had moved, beyond the evacuation zone. In response to delays in obtaining data from government officials, the Japanese citizens and nongovernmental organizations responded with grassroots efforts to collect the data themselves, with assistance from a number of organizations including sensor developers [19, 20].

Similar community-based initiatives are under way to collect and share environmental quality data related to hydraulic fracturing activities. One example is the Marcellus Citizen Stewardship Project, designed to provide local Pennsylvania citizens with tools and knowledge to monitor activities in the Marcellus shale and help protect community health. A key tool developed for this project is FracTracker, an interactive data platform that can be used to track drilling activity; it includes a map feature that shows where the fracking wells are located, as well as wastewater treatment plants [21]. (Note that these treatment plants play an important role in the region because produced water from that shale formation is not being disposed of via deep-well injection. Thus, these plants treat millions of gallons of that wastewater and release the effluents containing residual contaminants into local surface waters.)

A related initiative involves the partnership of a community-based alliance with a local college to develop citizen-focused training materials for monitoring water quality in streams and other surface waters affected by releases from hydraulic fracturing activities in the Marcellus shale [22].

4. Web-based information resources

In addition to the citizen monitoring initiatives noted above, a number of organizations have developed websites to share environmental information, and some of these have become go-to

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resources for the general public. In some cases, regulatory agencies also rely on these websites as part of their open and transparent communication efforts.

For nuclear power plants, government agencies have traditionally served as the primary source of environmental data related to releases. That has changed more recently, including in response to the Fukushima disaster and broad public desire for information about resultant radioactive contamination worldwide. To illustrate, the Woods Hole Oceanographic Institute is pursuing partnerships and community support for collection and sharing of data on radioactivity levels in the ocean, as part of assess potential impacts of the Fukushima releases [23]. Additional resources are available via non-governmental organizations, such as the Institute for Energy and Environmental Research (IEER) [24, 25] and Citizens for Nuclear Technology Awareness (CNTA) [26], which provide information about nuclear energy and ionizing radiation, including medical applications, that provide a public perspective beyond basic scientific data available via national and international agency websites. Selected online resources that emphasize citizen context are highlighted in Table 1.

For hydraulic fracturing, FracFocus [27] has emerged as among the most popular website for citizens, industries, and agencies alike. The online chemical disclosure registry available via this website provides information about wells fractured since early 2011. The current registry contains data for more than 68,000 groundwater wells, and it can be searched by location (e.g., state and county), with chemical selected from an extensive set of “ingredients” ranging from acrylamide/ammonium acrylate copolymer to zirconium compounds. Some states require oil and natural gas industries operating in their states to use this FracFocus registry to disclose information about their wells, and a number of industry personnel operating in other states without this requirement also voluntarily provide information via this website.

Considering the extensive and increasing amount of information available in this database, to facilitate efficient searches, the number of chemicals that can be included in a search was limited to 20, and the total number of disclosures returned from a single search was limited to 2,000. Recognizing that well development is projected to continue at an increased pace, registries such as FracFocus and other online databases are anticipated to benefit from ongoing ICT advances toward the goal of sharing information in real time among the broad and varied audience interested in environmental implications of hydraulic fracturing.

The Secretary of the U.S. Department of Energy (DOE) recently called on an advisory board to prepare a status report on FracFocus website. The Board’s findings [28] included a call for increased transparency about what chemicals are used in fracturing fluids, asking industry to report a complete list of their chemicals and quantities added at each well, using Chemical Abstract Service (CAS) numbers, and reporting a complete list of products (the Board indicates that by not linking the products to the chemicals used, proprietary information will be protected, so this approach would reduce the number of “trade secret” claims being made by industries to avoid reporting).

The Board also encouraged upgrading the website to achieve a more usable interactive database, including the following recommendations: (1) allow searching by any field (including additive purpose and trade name); (2) eliminating the 2,000-record display limit or adding a “next” function; and (3) including tools for searching and aggregating data by chemical, well, company, and geography, with one way of doing this being to release the full contents in raw, machine-readable form on the website. Note that data are submitted through XML files, an improvement over the earlier data submittal process using Excel sheets.
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<td>Volunteer monitoring of local water quality</td>
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<td>Grassroots information, including about towns with fracking bans</td>
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<td>Grassroots educational information, ranging from energy sources to medical radiation applications</td>
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*Table 1: Selected Web-Based Resources with Information Related to Nuclear Energy and Fracking*

Another community-based organization, FracTracker Alliance, also shares maps, data, and analyses online to communicate impacts of oil and gas development; this organization’s website covers information beyond the United States, including a link titled “worldwide resistance to hydraulic fracturing” that indicates locations of national movements, moratoria, and bans [29]. The website includes a mapping tool, FracTracker, which contains an index of pre-made maps that provides
information such as locations of wells drilled, those in violation of current requirements, watersheds, and storage facilities, based on available data. The organization’s earlier data/mapping platform (Data.FracTracker.org) is being phased out, as it has been replaced by the new FracTracker tool that runs on the Esri-based platform, ArcGIS Online. More features are being developed for the new FracMapper, anticipated to be available in fall 2014, including the ability to store and share the data behind the maps.

5. Summary
Growing public concerns about climate change and environmental health impacts related to energy production have led to increased consideration of alternate sources. Nuclear power and unconventional oil and shale gas development are among the options least favored by the public, with pollutant releases resulting from routine operations as well as accidents being among the key concerns. Advances in ICT approaches and the increasingly widespread accessibility of information resources and tools have facilitated community-based initiatives and broader data sharing that can directly contribute to more informed evaluations of energy options, toward more sustainable programs from the local to the global scale.

6. References

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