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ARTICLE *in* ECOLOGICAL ECONOMICS · JANUARY 2015

Impact Factor: 2.72 · DOI: 10.1016/j.ecolecon.2015.06.012

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Analysis

Fracking and environmental (in)justice in a Texas city

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ARTICLE INFO

Article history:

Received 11 May 2014

Received in revised form 7 May 2015

Accepted 15 June 2015

Available online xxxx

Keywords:

Distributive justice
 Environmental justice
 Mineral property rights
 Participative justice
 Royalties
 Split estate doctrine

ABSTRACT

Shale gas development (SGD) via horizontal drilling and fracking is touted for economic benefits and spurned for health and environmental impacts. Despite SGD's socioecological salience, few peer-reviewed, empirical studies document the distribution of positive and negative effects. The City of Denton, Texas has ~280 active gas wells and over a decade of SGD. Here we use an environmental justice framework to analyze the distribution of SGD's costs and benefits within Denton. Using data on mineral property values from 2002 to 2013 and gas well locations, we ask: who owns Denton's mineral rights (i.e. the greatest financial beneficiaries) and how does this ownership pattern relate to who lives near gas wells (i.e. those who shoulder the nuisances and health impacts)? Our results show that Denton's mineral wealth is widely distributed around the U.S., residents own 1% of the total value extracted, and the city government is a large financial beneficiary. In addition to distributional inequities, our analysis demonstrates that split estate doctrine, legal deference to mineral owners, and SGD's uniqueness in urban centers create disparities in municipal SGD decision-making processes. The environmental justice issues associated with fracking in Denton also provide one possible explanation for residents' November 2014 vote to ban hydraulic fracturing.

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1. Introduction

In 1982, Mitchell Energy connected the C.W. Slay #1 well in Wise County, Texas to their pipelines, marking the origin of commercial-scale natural gas production on the Barnett Shale. It also set in motion a global energy revolution. The work of Mitchell Energy founder, George P. Mitchell, on the Barnett brought together massive slickwater light sand hydraulic fracturing (i.e., fracking) with 3-D seismic imaging and horizontal drilling (Steward, 2007). By the turn of the 21st century, this innovation made the development of unconventional shale deposits of oil and gas economically viable. With few federal regulations and relatively high prices, oil and gas production in the United States boomed, in turn sparking controversy about fracking's costs and benefits.

The local effects of shale gas development (SGD) are especially controversial. Most concerns revolve around environmental and public health risks. However, despite growing evidence of carcinogenic emissions, water contamination, and negative health effects (e.g. Eastern Research Group, 2011; Oswald and Bamberger, 2012; Osborn et al., 2011; Kassotis et al., 2013; Hill, 2013; McKenzie et al., 2014; Schonkoff et al., 2014), uncertainties remain due to the limited number of long-term, peer-reviewed, empirical studies (Mitka, 2012; Thompson, 2012).

The extent that communities benefit from SGD also remains unclear. Some reports argue that local communities benefit from drilling through economic growth and job creation (e.g. King, 2012; Engelder, 2011). In the Barnett region, drilling proponents such as Energy In-Depth and the Barnett Shale Energy Education Council cite industry-funded studies (e.g., IHS Global Insight, 2011; Perryman Group, 2011; Perryman Group, 2014) supporting 'positive economic benefits' and 'job creation' narratives. However, Weber (2012) shows that economic gains in SGD boom areas are much lower than industry-funded groups often report and Brown (2014) finds modest employment and wage gains in SGD counties. Research also highlights economic costs; for example, Litovitz et al. (2013) estimate millions of dollars of socioecological damages from SGD air pollution in Pennsylvania. In addition to cost omissions, Kinnamen (2011) argues that most non-peer-reviewed economic studies on SGD are misleading and overstate economic benefits.

Skepticism about SGD's benefits also extends to city and town officials who increasingly pass measures ranging from tighter restrictions to outright bans. Although the extent that municipalities can legally regulate SGD remains unclear (Welch, 2012), there is little doubt that cities are becoming primary sites for jurisdictional battles (Briggie, 2013). Yet this policy environment has emerged in the context of a relative paucity of empirical research about SGD's costs and benefits.

As the nation's oldest and most heavily developed shale deposit, the Barnett offers an opportunity to analyze SGD's impacts on communities. Located in North Central Texas (Fig. 1), the Barnett underlies much of

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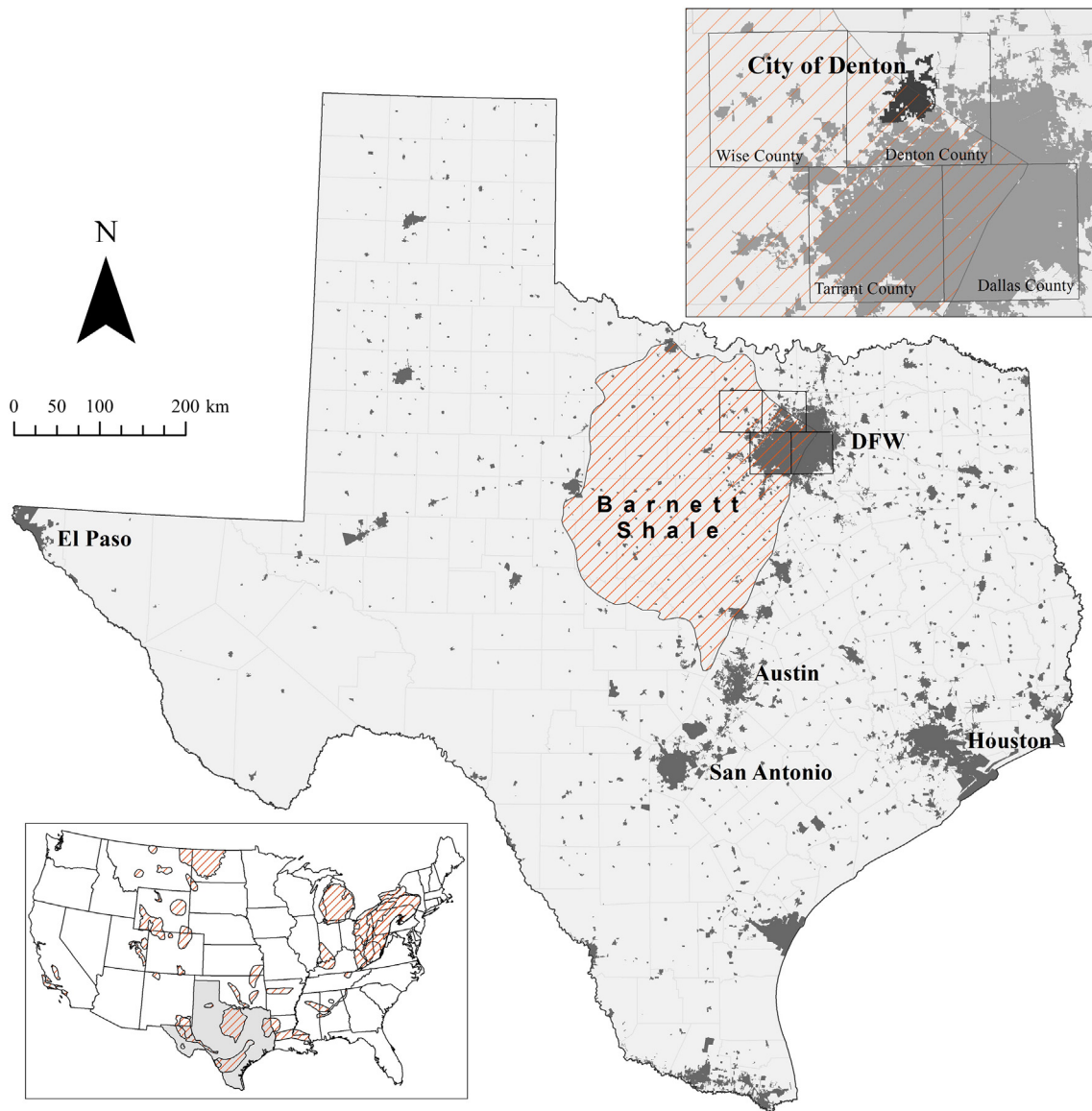


Fig. 1. Location of shale deposits in the United States (bottom inset); the Barnett Shale and urban areas in Texas; and the City of Denton in North Texas and relation to DFW (top inset).

the Dallas–Fort Worth Metroplex (DFW), the U.S.'s fourth largest metropolitan area (U.S. Census Bureau, 2011). Since 2000, nearly 15,000 shale gas wells were drilled into the Barnett bringing the total to over 17,000 and making DFW ground zero for urban SGD (RRC, 2013; Fry, 2013).

The City of Denton is in the north of DFW and at the Barnett's eastern edge. In 2002, Denton became one of fracking's first municipal hosts; in November 2014, it also became the first Texas city to ban hydraulic fracturing. With over a decade of SGD, Denton provides one of the few settings to examine how longer-term urban drilling affects communities both socially and economically. In this paper, we use an environmental justice framework and data on mineral property values from the Denton Central Appraisal District and gas well location data from the Railroad Commission of Texas (RRC) to examine the distribution of costs and benefits of SGD in Denton. Results show that the vast majority of direct SGD economic benefits are distributed elsewhere, while the social and environmental burdens remain local. In addition, these results about distribution of costs and benefits raise important questions about power and participation in decision-making processes.

2. The shale gas boom

2.1. Fracking and urban drilling

The Barnett Shale accounted for nearly 66% of U.S. shale gas production in the 2000s (EIA, 2011), and in terms of area, proven reserves, and total production to date, the Barnett is Texas' largest shale play. Many of the Barnett's most productive fields – and those initially targeted for production – underlie DFW. Some of the first urban wells were drilled in Denton and Tarrant Counties, which are demographically two of the fastest growing counties in the nation and geologically two of the Barnett 'core counties' where gas reserves are richest (RRC, 2013; US Census Bureau, 2011). This creates a perfect storm where surface development meets mineral extraction. At the start, drilling occurred on the outskirts of cities, but beginning in 2001 operators applied for permits to frack in more densely populated areas.

Federal power to regulate SGD is limited due to fracking's exemptions from the Safe Drinking Water Act and the Clean Water Act, as well as drilling's exemptions from the National Emission Standards for

Hazardous Air Pollutants and other federal environmental statutes (Kosnik, 2007). As a result, SGD regulation largely falls to state and local governments. In the U.S., property is divided into mineral and surface estates, which creates two important legal and regulatory considerations. First, if the mineral and surface estates are separately owned or severed, the Texas Supreme Court holds that the mineral estate is dominant over the surface estate and gives it priority to extract oil and gas (Riley, 2007). Second, split estate doctrine complicates SGD regulatory power in Texas cities. Outside of municipal territories, the RRC handles all oil and gas regulation and permitting. But within municipal territories, city governments have power to protect citizens' health, safety, and welfare. Thus cities can regulate many surface activities, including oil and gas well placement, tolerable noise levels, and other factors that affect quality of life (Riley, 2007). In December 2001, Fort Worth and Denton became the first cities to regulate SGD.

The purposes, objectives, and differences among DFW's SGD ordinances are discussed elsewhere (e.g. Fry, 2013). However, in general, municipal governments try to balance protecting mineral owners' rights with protecting residents' quality of life. As SGD expanded throughout DFW in the 2000s, more municipalities passed drilling ordinances. Likewise, as urban wells proliferated, so did citizen complaints. As a result, cities around DFW have amended their ordinances to address excessive noise, dust, traffic, light, diminishing aesthetics, and proximity to homes, schools, and churches. Several DFW cities also commissioned studies to evaluate the effects of gas drilling on property values, air quality, and cancer rates. For example, a Town of Flower Mound study found that property values decreased by 3% to 14% when located within 1000 ft (304.8 m) of wellheads (Integra Realty Resources, 2010); and an Eastern Research Group (2011) emissions study for Fort Worth found that most emissions from SGD were not detectable beyond 600 ft (182.9 m) from bore holes, but found high and unsafe concentrations of acrolein and formaldehyde (both carcinogens) well beyond that distance. To date, several municipalities have used these and similar findings to pass stricter SGD ordinances.

New research also points to possible links between fracking and human health. For example, Hill (2013) found that exposure to SGD within a 1.5 mile (2.5 km) radius increases the prevalence of low birth weight and McKenzie et al. (2014) found higher incidents of birth defects in areas with dense gas well concentrations. Kassotis et al. (2013) detected elevated concentrations of endocrine disrupting chemicals in surface water samples collected in dense drilling areas. McKenzie et al. (2012) found greater health risks from air emissions for residents living within 0.5 miles (0.8 km) of gas wells. Schonkoff et al. (2014) provide an extensive review of health studies related to fracking and note that proximity to SGD activities increases health risks. McDermott-Levy et al. (2013) provide a list of acute health problems reported by people living in communities with fracking, including burning eyes, dermatologic irritation, headaches, backaches, nosebleeds, etc. Although no peer-reviewed studies to date document health impacts on DFW residents, conflicts over urban SGD in the region largely center on disagreements over inequitable distribution of potential health and environmental costs, and potential economic benefits among local communities.

2.2. Environmental justice: distributive and participatory

Unlike resource boom towns, urban population growth in DFW is not directly related to SGD. In DFW, drilling activity either moved into pre-existing urban areas, or else housing developments were created near gas drilling sites. In instances of the former, some homeowners economically benefitted from SGD because they also owned the mineral property and received royalty payments.

But in other areas and in most newer neighborhoods that developed around existing drill pad sites, homeowners do not own their minerals. Surface property owners who do not own their mineral property receive no direct economic benefits from the minerals located below

their homes.¹ They do, however, receive some indirect economic benefits, particularly local property taxes derived from the value of the minerals, which contribute some funds to municipal governments and school districts (Weber et al., 2014). Local job creation is also often touted as another SGD indirect economic benefit.

Indirect benefits notwithstanding, DFW homeowners living in close proximity to drill pads have filed numerous complaints about noise and light pollution, and report nosebleeds, nausea, headaches and other symptoms (Goldenberg, 2013). In one neighborhood, forty-three homeowners filed a lawsuit against a drilling operator seeking \$25 million in damages (Sakelaris, 2014). Ultimately, the severity of negative side effects that homeowners and families experience depends on how close municipal governments allow gas drilling to be located to homes (Fry, 2013).

SGD in populated areas is an unprecedented industrial land use. For example, to Welch (2013), it is inappropriate to compare SGD to other land uses because of the privileged "legal status that allows operators to not disclose the chemicals used in hydraulic fracturing" (234). As well, unlike most industrial facilities, gas drilling pad sites are relatively small and most municipalities in the Barnett allow gas wells to locate in residential areas. Local governments, however, can use zoning and special use permits to protect residents' health, safety, and welfare. For this reason, municipal policies have become the institutional voice for residents vulnerable to the harms of drilling, but who (because they do not own the minerals) do not have a say in leasing decisions. Municipal governments thus face the challenge of often-conflicting prerogatives of surface and mineral property owners (Welch, 2012).

Environmental justice scholarship offers insight into spatial disparities among mineral owners who financially benefit from SGD and non-mineral owners who experience its negative externalities. From its inception in the 1980s, environmental justice activism and scholarship has produced evidence that minorities, the working class, and lower-income residents are subjected to disproportionately higher health and environmental risks in their neighborhoods and jobs (Bullard, 1990, 1993; Cole and Foster, 2001; Scholsberg, 2007). Much of this scholarship focuses on the siting of landfills, refineries, power plants, and other industrial hazards and how the distribution of environmental harms fall on communities disenfranchised from the decision-making process (Cole and Foster, 2001). Of course, the environmental justice story in SGD is different from typical large industrial hazards, because mineral owners who lease mineral rights for SGD can cause neighbors to face disproportionate environmental impacts (Wiseman, 2013). According to Shrader-Frechette (2002, 3), an environmental injustice occurs "whenever some individual or group bears disproportionate environmental risks...or has unequal access to environmental goods...or has less opportunity to participate in environmental decision-making". Two kinds of justice are latent in this definition: 1) distributive justice, which pertains to the allocation of harms and benefits, and 2) participatory (or procedural) justice, which pertains to involvement in the decisions that affect one's life.

There are also two kinds of decisions involved in SGD policy: private decisions that pertain mostly to the leasing of mineral rights, and public decisions that pertain to federal, state, and local regulations. Non-mineral owners are essentially excluded from the private decisions, as the mineral owners not only receive the direct monetary benefits, but also hold a great deal of state-sanctioned power to decide if and how SGD proceeds. Of course, in Texas and many other states, mineral owners who holdout or refuse to lease their mineral rights can be "force pooled," in which case they still receive payment but effectively have their voice nullified (Baca, 2011). Public decisions about urban SGD affect the distribution of benefits and harms in several ways, including tax rates, pollution mitigation measures, and setback distances

¹ Although in some instances surface owners financially benefit from surface-use contracts signed with operators, this is not typical among suburban homeowners, let alone renters, in Denton.

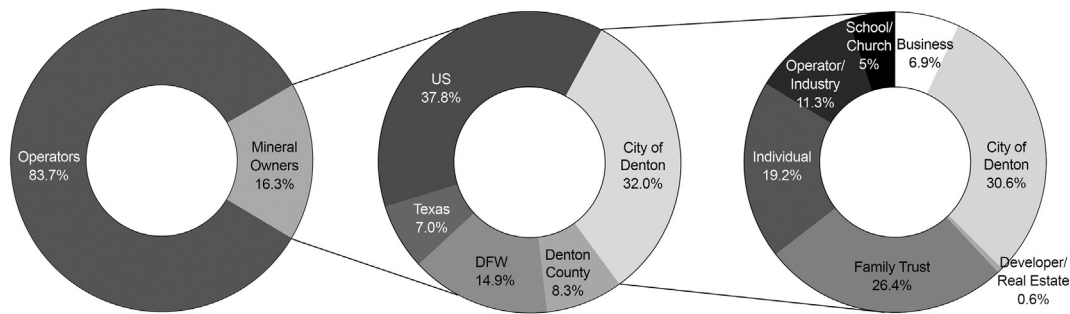


Fig. 2. Distribution of the City of Denton's mineral values from 2002–2013 based on Denton County Appraisal District. From left to right: distribution among operator working interests and mineral owner royalty interests based on the sum of the average appraised values, \$405,372,172; geographic distribution of mineral owners based on the sum of the average appraised values; and distribution of the average appraised values among mineral owners, classified by type, with mailing addresses in the City of Denton.

between gas wells and homes. When it comes to participation in decision-making, non-mineral owners living in close proximity to gas wells turn to public venues, especially municipal governments, to represent their voice.

The degree of participation in decision-making processes can be used to judge whether a given distribution of environmental benefits and burdens is just or unjust. For example, an unequal distribution of environmental burden or risk is just when the person receiving the larger share of the burden is meaningfully involved in the decisions leading to that distribution and freely consents, with full information and no coercion, to the outcome. Indeed, just participation is a function of informed, non-coerced consent—a concept much discussed in bioethics (Manson and O'Neill, 2007)—and also integral to environmental justice (Shrader-Frechette, 2002; Ottinger, 2013). Central to both is a sense that if an industrial activity is going to be sited near your home or if an experimental drug is going to be injected into your body, you ought to be involved in that decision.

When deciding whether or not to place gas wells in neighborhoods, distributive and participatory justices are both at stake. That is, there are questions about how revenues should be allocated and about who should decide where, how, and whether to drill. For this reason, the City of Denton offers a compelling look into the environmental justice implications of SGD in communities.

3. The City of Denton and shale gas wells

The City of Denton has a population of ~120,000 and covers an area of ~62 miles² (~160.6 km²). There are roughly 280 producing gas wells inside city limits and 212 in the extra-territorial jurisdiction, the majority drilled after 2001. Early in the Barnett boom, the city only issued fire permits for drilling permit applications, which did little more than enforce a 100 foot (30.5 m) setback distance between wellheads and built structures (as per the International Fire Code). In late 2001, the city established a gas well drilling and production ordinance, later mandating a 500-foot setback between gas wells and protected uses (such as homes and schools). The city's drilling and production ordinance also required gas well operators to comply with several other rules, including minimum insurance coverage and signage and landscaping around pad sites.

Although SGD in the City of Denton has increased over time – from seven wells in 2001, to 137 in 2005, 230 in 2010, and 280 in 2014 – only in 2009 did the City Council take notice of citizen complaints. In 2009, Denton permitted an operator to drill three controversial gas wells close to homes, a public park, and a hospital (see Fig. 4c). Citizen backlash led the City to impose a moratorium and form a task force to help revise its gas drilling ordinance. A new version of the ordinance, adopted in January 2013, increased the setback distance between pad sites and protected uses to 1200 feet (365.8 m).

About nine months after approving the new ordinance, another operator drilled three gas wells within 250 ft (76.2 m) of homes in a

southwest Denton neighborhood. In this case, the pad sites predated a housing development where no homeowners owned minerals, so the operator's right to drill was grandfathered or 'vested'. In such situations, Denton's ordinance allowed for home construction to occur less than 250 ft (76.2 m) from pre-existing pad sites. But the close proximity of wells to homes (where homebuyers were not adequately notified about gas wells, potential future drilling, or fracking) alarmed citizens, reignited debates about the adequacy of the city's ordinance, and contributed to a citizen-led campaign to ban fracking in the city.

In November 2014 citizens voted to ban hydraulic fracturing in the city. However, despite Denton's fracking ban and the national debate about the pros and cons of SGD in populated areas, there are no systematic assessments of local-scale distributions of costs and benefits. In particular, it remains unclear who owns mineral rights (i.e. those who stand to gain the greatest financial benefits from drilling) and how this pattern of ownership relates to who lives near drilling sites (i.e. those who pay the most direct costs in terms of nuisances and health impacts).

4. Data and methods

This study uses appraised mineral property values as a proxy for SGD royalty payments to examine where, and among whom, monetary benefits from SGD in the City of Denton accrue. The appraised value of mineral properties from 2002 to 2013 comes from the Denton Central Appraisal District (DCAD) and gas well latitude and longitude data comes from the RRC. Wardlaw Appraisal Group, LC uses initial production rate, decline rate, gas price, lease operating expenses, productive life of well, and severance tax expense in a discounted cash flow calculation to estimate Denton County's mineral values (Wardlaw Appraisals Group, 2013).² Although appraised values are not always equal to the actual monetary values accrued from SGD, it is extremely difficult to

² Discounted cash flow analysis estimates the entire value of the gas well. The sum of the discounted future revenues from each month of the well's projected life is the fair market appraised value of the well. After the fair market appraised value of the well has been calculated, the value is distributed equally to each mineral interest owner based on the ownership type and percentage (Wardlaw Appraisal Group 2013). The discounted cash flow is a projection of the future monthly income that, in the case of Denton, is calculated using 1) the initial production rate (which is determined from RRC production records), 2) the rate of decline (calculated from the production history trend), 3) price of gas (previous year price multiplied by the market condition factor), 4) the lease operating expenses (based on the average monthly lease operating costs from the preceding year), 5) productive life of the well, 6) the severance tax expense (normal rate is 7.5% for gas), and 7) the discount rate (calculated from rates used by financial institutions and Texas Comptroller's annual gas discount rate).

The discounted cash flow appraisal represents the calculated recoverable reserves and the corresponding future income for each lease. Because it is for future reserves, the appraisal value is not a real-estate, accounting, or statistical comparison of the prior year's value (i.e. an 'in-place' reserve calculation that estimates the original gas in place at the well's completion and deducts each year's production). The discounted cash flow method is the standard valuation method for assessing royalty payments for oil and gas mineral interests in Texas (Anderson, 1997).

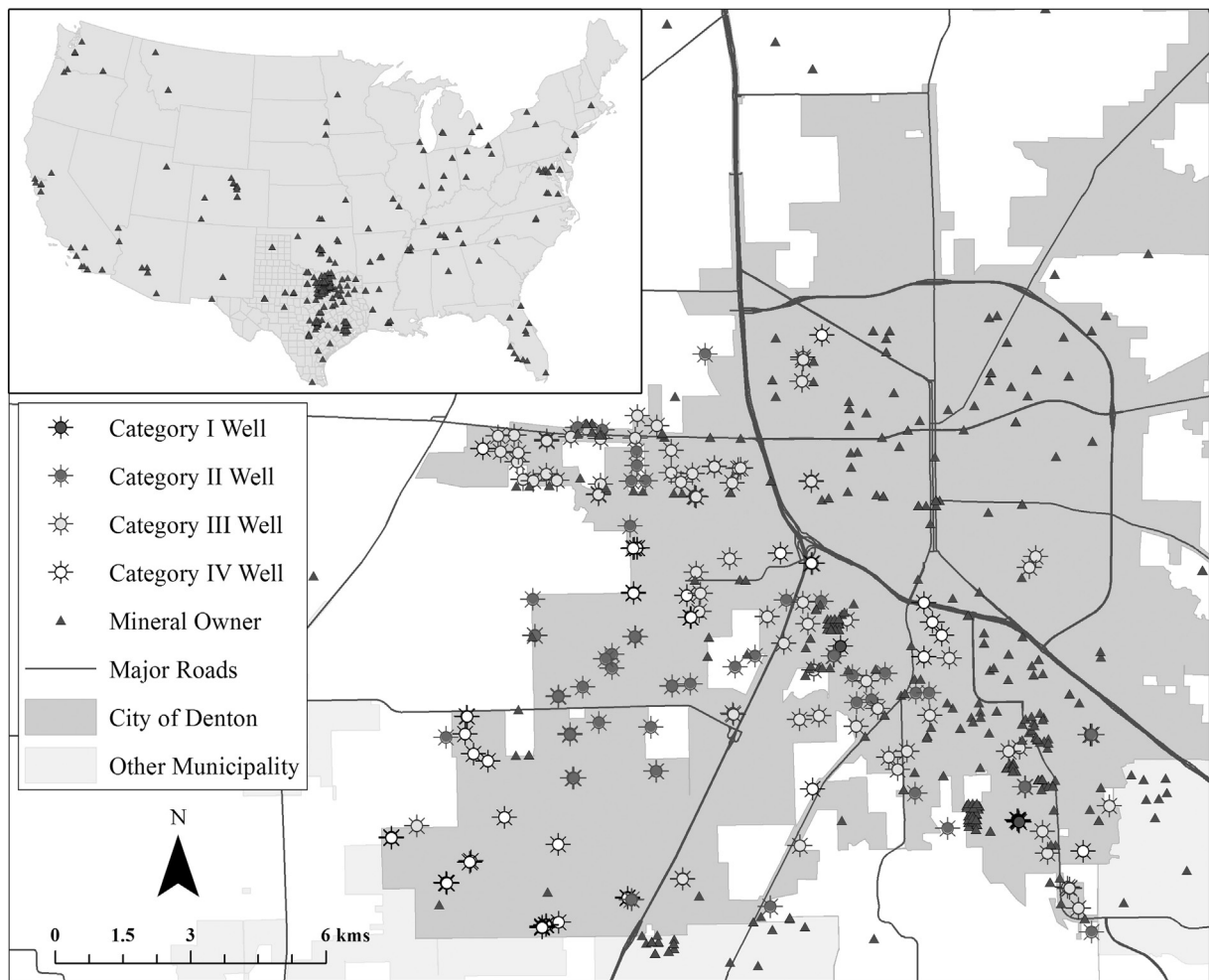


Fig. 3. The spatial arrangement of the City of Denton's 2002–2013 Barnett mineral owners ($n = 1455$) and gas well units ($n = 194$) discussed in this study. The inset shows the distribution of owners' mailing addresses throughout North America. In the City's territory, drilling units are divided into four categories based on the total number of mineral owners (see Table 1).

access private information on royalty payments, so appraised values are an appropriate proxy.

In addition to appraised value per year, the DCAD data provides names and mailing addresses for mineral owners, a legal description of each well, type of mineral interest, lease or unit name, operator name, lease and property ID, and percent mineral interest owned. As a first step, we removed any appraised properties that lacked information on ownership, mailing address, or had no value assigned to the property from 2002 to 2013. Second, we isolated the share of value assigned to gas well operators who develop and operate the mineral lease (these are listed as 'working interests' in the DCAD data). For most of our analysis of the distribution of mineral values, we excluded 318 working interests assigned to 38 different operators. Our rationale for excluding operators from the analysis is that in most cases they are not 'owners' of minerals. Rather, they lease the mineral rights from owners. Ultimately, mineral owners decide whether or not to drill (keeping in mind the above caveat about forced pooling) and, thus, to create the associated risks of potential harms (e.g., property damage and devaluation, potential accidents and illnesses) to those living nearby. We used the ArcGIS Online World Geocoding service in ArcCatalog10.1 (ESRI, 2012) to assign latitude and longitude information to the DCAD data, and mapped owner mailing addresses and RRC gas wells.

5. Results

Between 2002 and 2013, the sum of the average appraised values of the City of Denton's 5241 Barnett mineral interests, including operators'

working interests, equaled \$405,372,172 (average values are used in order to standardize appraised values from multiple years). Fig. 2 shows the breakdown of the total value of the city's Barnett mineral interests. The sum of the average working interests for all 318 operators is \$339,169,817 or 83.7% of the total value, and the sum of the averages of the remaining 4923 shares of the city's mineral interests is \$66,202,354 or 16.3% of the total. Fig. 2 also shows the spatial distribution of owner's mailing addresses based on the sum of the average appraised value of each share. Properties with owners who have mailing addresses listed in the City of Denton receive \$21,617,684 of the total of the mineral owners' appraised values. Property owners with mailing addresses outside the city in Denton County receive \$4,194,763 of the mineral value, property owners in DFW (Tarrant and Dallas Counties only) receive \$10,104,335, property owners in Texas (not Denton, Dallas or Tarrant Counties) receive \$4,755,860, and property owners based in the US outside of Texas receive the largest share, \$25,529,711.

There is an uneven distribution of financial value among mineral owners with mailing addresses in the City of Denton. These owner entities include individual homeowners, business ventures, family trusts, operators/energy industry, schools/religious institutions, the city government, and developers/realtors (See Fig. 2). Among city-based owners, the largest share (valued at \$6,615,011) goes to the City of Denton itself, followed by family trusts (\$5,707,069). The third largest share (\$4,150,595) goes to individual homeowners who comprise 90% of the city-based owners. Although individuals comprise the vast majority of owners who live in Denton, they control only 19% of the value that stays in the city, or 6.3% of the \$66,202,354 value not going to operators,

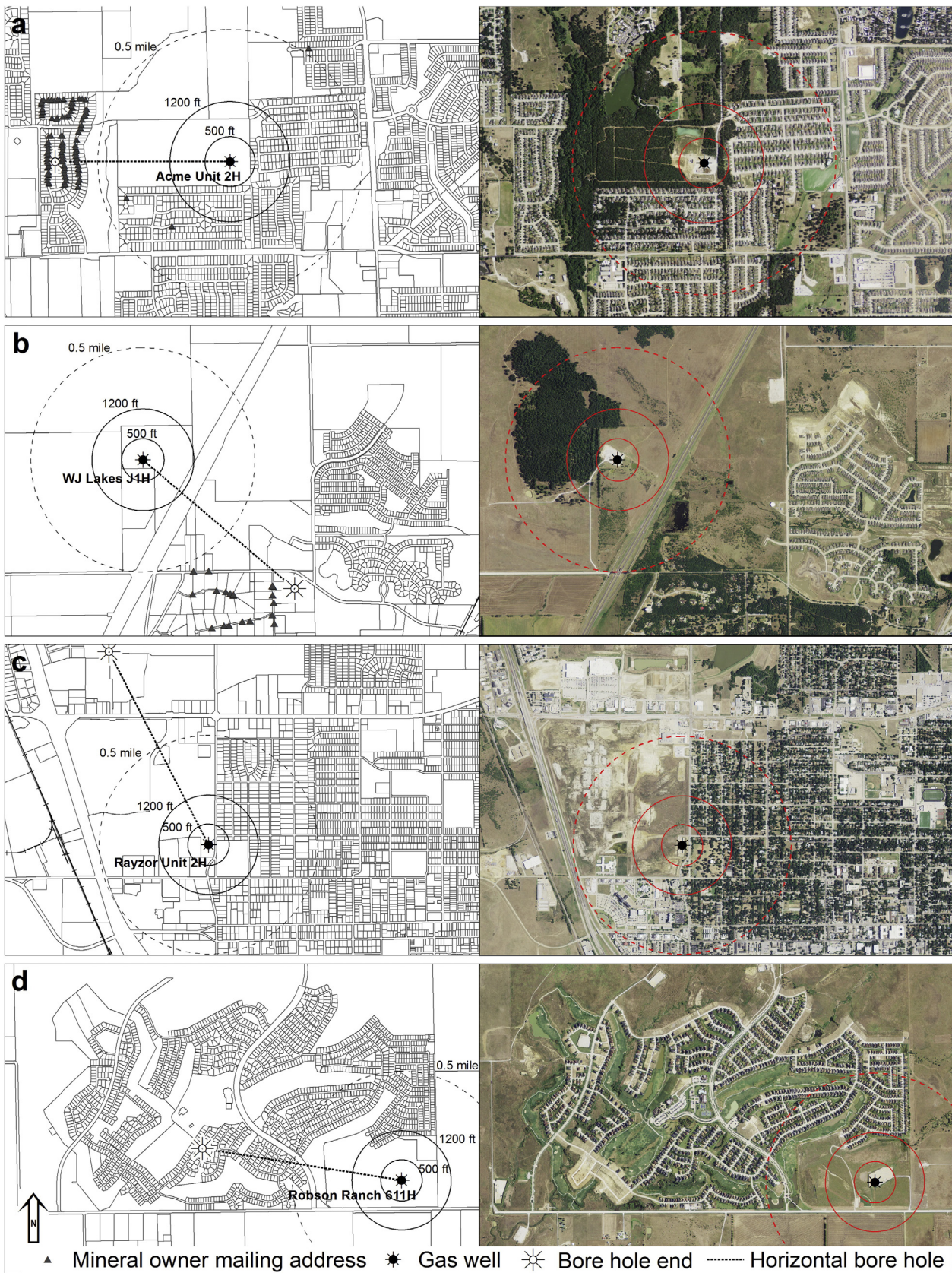


Fig. 4. Selected gas well units in Denton, Texas: a) Category I, Acme Unit 2H (2717 m depth), b) Category II, WJ Lakes Unit J1H (2592 m depth), c) Category III, Rayzor Unit 2H, d) Category IV, Robson Ranch 611H (2500 m depth). Paired images show surface parcels and mineral owners (left) and aerial image of same area in 2012 (right) as well as 500 foot, 1200 foot, and 0.5 mile buffers (sources: DCAD; RRC; National Agriculture Imagery Program).

Table 1

Mailing addresses for the City of Denton's mineral property owners. Columns show the number of mailing addresses in each location (note that U.S. includes four properties owned by one individual with a mailing address in Ontario, Canada). Rows are the four drilling unit categories.

Category	Mailing address of mineral property owners					Total
	City of Denton	Denton county	DFW	Texas	U.S.	
I	1120	98	82	122	113	1537
II	591	407	521	485	552	2556
III	175	91	248	137	105	758
IV	12	0	14	8	38	72
Total (%)	1898 (38.6%)	596 (12.1%)	865 (17.6%)	757 (15.4%)	807 (16.4%)	4923 (100%)

or 1% of the \$405,372,172 total appraised value, including operator interests.

Mineral owning homeowners in Denton receive a small percentage of the appraised value because most have relatively small-sized mineral holdings. To demonstrate differences among the mineral holdings of the 194 gas well units, we identified four categories based on the number of mineral properties per unit (Fig. 3 and Table 1). Category I consists of six units that have 115 to 346 mineral properties per unit; Category II consists of 64 units with 20 to 84 properties; Category III consists of 72 units with 4 to 19 properties; and Category IV comprises 52 units with 1 to 3 properties. Fig. 3 maps the spatial distribution of gas well units based on these categories, as well as mineral owner addresses.

Among the four gas well unit categories, the location of mineral property owners' mailing addresses varies (see Table 1). Most Category I property owners, 73% (1120 of 1537), are residents of the City of Denton. Category II and Category III property owners are distributed fairly evenly among all locations. Most Category IV property owner addresses (83%) are located outside of the city. Indeed, the largest share of the city's mineral wealth is controlled by Category IV owners living in the greater U.S. who control \$19,688,397 (29.7%) of the appraised value that does not go to operators. This is mostly a retirement community developer based in Sun Lakes, Arizona.³ Thus, for all 194 gas well units, only 38.6% of the 4923 properties have addresses located in the city. Among them, most are small-sized shares in Category I wells.

We selected four units, one from each category in Table 1, to better illustrate gas well proximity to local mineral owner and non-mineral owner homes (Fig. 4). Different distance buffers are drawn around each well. As noted, in 2013 Denton's legal setback distance between homes and gas wells increased from 500 to 1200 ft (152.4 to 365.76 m). However, homes can be located closer than setbacks allow if the operator receives city government approval (referred to as a variance), if the gas well plat was permitted prior to setback adoption (vested rights), and/or if homes were built next to an existing gas well. In addition to 500 and 1200 foot buffers, Fig. 4 also shows a 0.5 mile (0.8 km) buffer based on the McKenzie et al. (2012) radius for greatest emissions health risks.

The Category I Acme Unit 2H has 10 houses within 500 ft (152.4 m) and 177 houses within 1200 ft (365.76 m) (Fig. 4a). The closest mineral-owning home associated with the unit is 1734 ft (528.6 m). Most housing developments in close proximity were built in the 1990–2000s. The City of Denton owns the largest mineral interest (3.4% share). In addition, 193 Acme 2H mineral property owners have city addresses, and the average appraised value for most (177 of 193) is less than \$70. These owners combined shares equal \$6410 or 2.44% of the unit's total appraised value (excluding operator interest). Despite city-based addresses comprising the majority of mineral owners, the majority of the unit's appraised value (66.8%) goes to entities outside the city.

³ In 2011, the Arizona-based residential care developer established a satellite office in Denton.

The closest home to the Category II W.J. Lakes Unit J1H is 2727 ft (831.2 m) and is owned by a mineral owner (Fig. 4b). Most mineral owner homes in Fig. 4b were built from 2001 to 2008, and the neighborhood to the northeast was built in 2007–2008. A Fort Worth real estate investment firm owns the largest mineral interest (4.8% share). The average value for 18 of 65 mineral owner's homes visible in Fig. 4b range from \$1203 to \$7953. Although the unit is inside city territory, all of these homes reside outside of the city. Most of the unit's value (85.6%) also goes to mineral owners who do not live in the city.

In 2010, three gas wells (Razor Unit 1H, 2H, and 3H) were drilled in a planned, mixed-use development area (Fig. 4c). Due to their location, controversy arose before and after the wells were permitted on October 6, 2009 (Brown, 2010; see above). The closest home to the Rayzor Unit 2H is 295 ft (90 m) from the bore hole. The closest home with a mineral value associated with the unit is 9186 ft (2799.8 m). Two houses are within 500 ft (152.4 m) and 52 homes are within 1200 ft (365.76 m) of the well. Houses to the east were built prior to the 1980s. A hospital to the south was built in 2003. A real estate investment firm with a Denton PO Box address owns the largest mineral interest (18.6% share). Combined, the real estate investment firm and non-Denton-based owners receive the majority of the unit's financial benefits (98.7%).

Between 2008 and 2010, 17 gas wells were drilled on three pad sites located around a retirement community (Fig. 4d). An Arizona-based residential care developer is the sole beneficiary of each unit. No homes are within 500 ft of the unit, 27 homes are within 1200 ft; the closest is 963 ft (293.5 m). Construction of the active adult retirement community began in 2001, long before any wells were drilled. The developer of the community is also the largest beneficiary of drilling in the city (Table 2).

Family trusts are other large beneficiaries of Denton's minerals (Table 2). For example, one family and their trusts own 25 of the 64 Category II gas well units located in southwest Denton on ranchland. The largest individual mineral owners have Dallas and New Jersey mailing addresses. Several of the top 20 are real estate investment firms. As well, several addresses are PO Boxes. In total, PO Box addresses comprise 831 of the 4923 properties (16.9%) and \$30,177,233 of the \$66,202,354 appraised values (45.6%). The vast majority of PO Box address owners are trusts and businesses. PO Boxes likely do not represent final locational destinations for mineral values or physical residences of mineral owners. As Table 2 makes clear, several of the largest supposedly "Denton-based" owners are not likely Denton residents.

Finally, the City of Denton is the second largest SGD beneficiary in the city. The City owns property in 22 gas well units appraised by DCAD; most of this value comes from nine gas wells located at the City's Airport where royalty payments from 2006 to 2012 amounted to \$11,215,271 (City of Denton, 2014a). Royalties and interest from Airport gas wells comprise the majority of financial resources for the Airport Enterprise Fund that finances major airport projects, including its current business and master plans (City of Denton, 2014a). In addition, the City uses royalty, pooling, interest, and lease revenue (>\$2.5 million) from non-Airport gas wells to fund projects with no-ongoing costs and park system projects. Since 2006, these include: Planning Department software (\$600,000), Transportation Department fiber-optics (\$392,900), an update to the City's comprehensive plan (\$600,000), a water slide (\$250,000), soccer fields (\$950,000), a golf driving range (\$200,000), park property acquisition (\$500,000), and other park enhancements (City of Denton, 2014a).

6. Discussion

6.1. Distributive justice

The results above indicate distributive inequities among those receiving financial benefits and those experiencing SGD's burdens in Denton. Excluding operators' working interests, entities based outside of the City of Denton own at least 68% of Denton's assessed mineral values

Table 2
The 20 largest recipients of Denton's minerals. Columns organized by owner type, sum of average appraised mineral property values, and city and state address.

Owner type	Sum of avg. values (2002–2013)	Mailing address		
		City	State	Type
Residential care developer	\$21,776,449	Sun Lakes	AZ	Street
City of Denton	\$8,088,564	Denton	TX	Street
Real estate investment firm	\$1,727,784	Denton	TX	PO box
Family trust	\$1,691,094	Denton	TX	PO box
Family trust	\$1,589,016	Denton	TX	PO box
Family trust	\$1,459,731	Denton	TX	PO box
Real estate investment firm	\$921,585	Fort Worth	TX	Street
Private school	\$683,369	Denton	TX	Street
Real estate investment firm	\$576,426	Dallas	TX	Street
Family trust	\$572,694	Highland Village	TX	Street
Real estate investment firm	\$542,083	Denton	TX	Street
Individual	\$509,353	Dallas	TX	Street
Individual	\$509,353	Dallas	TX	Street
Individual	\$488,267	Marlton	NJ	Street
Food packaging company	\$439,455	Denton	TX	Street
Modular home developer	\$406,169	Denton	TX	Street
Real estate investment firm	\$375,976	Plano	TX	Street
Modular home developer	\$374,057	Dallas	TX	Street
Individual	\$361,673	Fritch	TX	Street
Individual	\$361,291	Denton	TX	Street

from 2002 to 2013. Among this group, the single largest beneficiary is a retirement community developer in Arizona. Other major absentee owners include families with legacy ranch properties. Historically, large land owners and their families have been the primary beneficiaries of oil and gas development in Texas (Goodwyn, 1996) and this group is likely among the main beneficiaries of Barnett Shale extraction.

Although small-sized mineral properties predominate, the wealth generated from these is a fraction of the total value. For example, individual homeowners in Denton own just 6.3% of the total value held by all owners or 1% of the total value including operator shares. Many gas wells are located close to residents' homes (see Fig. 4) and proximity increases the likelihood of experiencing negative health effects (Schonkoff et al., 2014; Hill, 2013; McKenzie et al., 2012). Indeed, distance to source is the primary explanatory variable for toxicological side-effects of environmental pollution (Meade and Emch, 2012). In this sense, non-Denton based mineral owners, 61.4% of owners, receive monetary benefits (substantial in some cases) and, because of their distance from SGD activities, experience none of the risks. In short, there is a disproportionate distribution of SGD's burdens and benefits in Denton, with resident non-mineral owners paying the environmental and health risks without receiving direct economic benefits and others reaping the benefits without being exposed to risks.

There are several considerations here in terms of environmental justice. First, it is difficult to identify all direct financial beneficiaries of urban SGD in Denton due to inadequate information. For example, the DCAD database does not include several gas wells located in the city and does not specify if mailing addresses are where mineral owners actually reside. The presence of PO Box addresses further complicates the latter. As well, there are other direct benefits, such as confidential surface use agreements and bonus payments that do not show up in the DCAD database.

Second, accounting for all of the economic costs of SGD is complicated (Litovitz et al., 2013). For example, although some studies show a decrease in home values near gas wells (e.g., Integra Realty Resources, 2010), assessing SGD's cumulative impacts on residential property values is difficult because formal data are hard to access (Radow, 2014). Moreover, operators have legal non-disclosure agreements that further hamper the free flow of information about SGD's associated costs (Radow, 2014).

Third, any assessment must also account for indirect economic benefits such as tax revenues and city projects funded by SGD on public lands. In Denton, despite hosting 280 gas wells, mineral property taxes amount to just 1% of total property tax revenues and a smaller

percentage of the city's total operating budget (DCAD, 2013). In addition, while local job creation could be another indirect economic benefit of SGD in Denton, none of the operators drilling in city territory have locally-based headquarters and the mining industry accounts for only 0.27% of city employment (Denton Economic Development Partnership, 2014). As these numbers indicate, SGD accounts for a tiny portion of Denton's economy. Other indirect benefits of SGD pertain to the electricity, heat, plastics, and other consumable commodities made possible by natural gas. One conception of environmental justice holds that people who consume the most of such commodities should bear most of the environmental burdens associated with their production (Wenz, 2001). However, auditing people's consumption and ensuring they bear a proportionate share of the burden (however that could be measured) makes this proposal impractical.

Fourth, each gas well site is unique in terms of surface and mineral ownership, and proximity of homes to gas wells. For example, the Acme 2H and Rayzor Unit 2H cases feature many homes of non-mineral owners located in close proximity to gas wells (Fig. 4). Moreover, the vast majority of Acme 2H mineral beneficiaries who actually live in Denton receive small financial benefits (2.4% of the value of the well). On the other hand, for the W.J. Lakes Unit J1H example, several mineral-owning households are located close to the unit – though they fall outside city territory – and closer than homes of non-mineral owners (Fig. 4b). Overall, and throughout the city, the number of non-mineral-owning homes located close to gas wells is much greater than mineral-owners' homes and, because of vested rights and variances, many non-mineral-owning homes are located closer than the 1200 foot (365.8 m) setback distance.

Fifth, while people should be able to choose whether or not to live in a hazardous area, they are not always able to do so. For example, arguments for individual actor agency generally note that people choose what risks to bear and to what degree, but neglect the role of broader structural forces (e.g. racial, social, economic) on peoples' decisions. Environmental justice scholars have long pointed out that structural forces preclude actor agency when it comes to distributional injustices among marginalized groups, who are marginalized precisely because of limited socioeconomic opportunities (Schlosberg, 2007). Moreover, arguments for actor agency to relocate away from industrial hazards assume that individuals not only fully comprehend proximate environmental and health risks, but can also foresee future risks. To Ottinger (2013), stories of people who moved to areas and did not think there was a serious hazard but came to believe so after living there are often cast as "victims not of structural injustice but of their own poor choices" (252). In this case,

'choice' implies that adequate information is available to communities asked to give their consent to hazardous activities (Ottinger, 2013). For this reason, determining whether the inequity in the distribution between those receiving the benefits and those experiencing the burdens is environmentally unjust depends also on the inclusivity of the decision-making process and the level of disclosure and informed consent granted to those suffering the burdens.

6.2. Participatory justice

Environmental justice is affected by the type and level of participation in decisions about where to site refineries and similar hazards (Cole and Foster, 2001; Shrader-Frechette, 2002). Although the split estate is justified as a way to better manage resource extraction (Riley, 2007), it hampers the ability of nearby non-mineral owning residents to participate in decisions about surface activities. Beneficiaries of split estates not only own the mineral value, but also wield disproportionate power in determining if and along what terms SGD will take place. Non-mineral owning residents, on the other hand, have less power and are largely disenfranchised from these decisions. As such, split estate doctrine (and not race, income, or class) creates conditions for participatory environmental injustices in SGD communities.

In order to participate in SGD decisions, residents living in close proximity to gas wells turn to the city government – the institutional voice for non-mineral owning surface dwellers who do not have a say in mineral-leasing decisions. But as our results demonstrate, Denton's municipal government is a major financial beneficiary of drilling in its territory. Thus, the city government is caught in a potential conflict of interest between optimizing its own financial self-interest through minimally regulating drilling and acting as the institutional voice of non-mineral-owning citizens to adequately manage a risky activity. Of course, the City invests its gas well revenues into airport, park, and department projects that allow non-mineral-owning citizens to experience some indirect benefits, though to what extent citizens experience the benefits from these projects is hard to quantify.

Receiving direct financial benefits from SGD does not necessarily compromise the decision-making or political processes in Denton, however, because the city government is made up of local citizens who, at least in theory, represent the views of Denton residents. As well, citizen advisory committees and public hearings on SGD allow non-mineral owners excluded from private mineral-leasing decisions to exercise their participatory power (Guana, 1998). Indeed, Denton's 2013 gas well ordinance was a direct outcome of citizen involvement and the evolving political process. The stricter 2013 ordinance is evidence of participatory decision making by citizens and elected officials whose knowledge about SGD's externalities came from first-hand experiences and a growing body of research.

Nevertheless, there remained two problems with the 2013 ordinance that hampered more meaningful participation in SGD decision making. First, the ordinance only applied to new gas wells proposed in existing neighborhoods and not to vested gas wells permitted by the City before 2013 (260 in city territory and 202 in its extraterritorial jurisdiction). Despite the growing body of scientific knowledge on the health and environmental effects of fracking, SGD communities are stuck living under older gas well regulations enacted when such knowledge about health and environmental risks was not available.

For full participatory justice, communities must have ongoing opportunities to consent to environmental hazards as scientific understandings of those hazards evolve (Ottinger, 2013). But vested rights prevent communities from amending regulations written when health and environmental risks were not fully understood. Because of vested rights, Denton was stuck with SGD policies of the past and older gas wells remained largely immune to regulatory improvement. More pernicious for Denton and other SGD communities, vested rights apply to entire pad sites (and in some cases substantially larger platted areas) and not just to the bore holes, so new gas wells can be drilled on existing

pad sites (or larger platted areas) adhering to older regulations and without public hearings or public consent. According to Ottinger (2013), for the 194 gas well units examined in this study to be considered just, as well as any new gas wells planned on existing permit sites, each would need to meet the criteria of the 2013 ordinance and be subjected to future reviews to allow the renewal or withdrawal of community consent as information about SGD continues to advance.

Vested rights are significant problems for SGD communities, as confirmed by a 2014 white paper produced by the Denton city government (City of Denton, 2014b). In the document, the City asks the Texas Legislature to clarify the vested rights law that, according to the City, restricts its authority to address SGD's impacts. In particular, the changing nature of 'projects' and 'endeavors' as written in the vested rights law make it very difficult to apply the law in SGD cities (City of Denton, 2014b). Therefore, the city argues that to protect "the health and safety and the quality of life of a municipality's citizens" SGD cities must be granted more flexible interpretations of vested rights (City of Denton, 2014b).

A second problem with the 2013 ordinance involves subsequent property development around gas wells. To Welch (2013), subsequent developers often are viewed as "coming to the nuisance, with the implication that an apartment builder (not the future apartment resident), for example, 'knows what he or she is getting into'" (236). When apartments or new homes are built in close proximity to vested gas well sites potential residents and homebuyers are not given full disclosure about the presence and risks associated with those gas wells. Having adequate information about the nature of one's choice – in this case whether or not to live near a gas well – is necessary for giving meaningful and fully informed consent (Faden and Beauchamp, 1986). Where local environmental hazards may be present and people fully understand associated risks, the act of moving into the neighborhood implies consent and an environmental injustice does not occur (Ottinger, 2013). In SGD communities today, however, there are few if any policies mandating that 'meaningful information' about SGD's risks be conveyed to potential homebuyers or renters. For example, in Denton, often only the existence of gas wells, and not hazards, is conveyed to homebuyers in one, short paragraph among pages of documents signed at home sale closings (Author interviews with new homebuyers, May and June 2014). As well, potential homebuyers cannot know exactly when drilling and fracking will return to a preexisting pad site; nor can they identify many potential risks associated with fracking given the privileged legal status of operators to not disclose some of the chemicals used in hydraulic fracturing (Welch, 2012). As a result, even a reasonable amount of due diligence by a potential homebuyer might not reveal the full extent of SGD's associated nuisances, health risks, and other negative effects.

Given vested rights issues and subsequent housing developments, a more just participatory decision-making process in Denton would involve less rigid and more flexible vested rights clauses within the city ordinance to allow residents to amend earlier decisions (i.e. re-consent to SGD) as new scientific information about hazards becomes available. The ordinance also would mandate disclosure of meaningful information about SGD risks to renters and homebuyers.

6.3. Legal murkiness of urban SGD

As noted above, SGD is a unique urban land use that does not compare easily to other land uses regulated by city governments with zoning and special use permits. Indeed, property owners and developers have reasonable expectations for city-mandated, land-use regulations. However, unlike surface owners and developers who have multiple land-use options, mineral owners only have one, the production of oil and gas (King and Bryan 2004). With SGD, municipal officials not only contend with the surface placement of an industrial activity in residential areas, but also must account for mineral owners' rights to access their property. Here again, the vertical severance of estates creates unique problems (Riley, 2007). Specifically, municipal policies that

deny or substantially restrict a mineral owners' access to vested mineral rights could give rise to compensatory regulatory takings challenges (Riley, 2007).

Regulatory takings occur when a government regulation “denies the landowner all economically viable use of the property or totally destroys the value of the property” (Welch, 2012, p. 2). In other words, through a regulation or ordinance, the government exercises its power of eminent domain yet does so without fairly compensating the private property owner.⁴ The idea of just compensation addresses private citizen rights to prevent government “from forcing some people alone to bear public burdens which, in all fairness and justice, should be borne by the public as a whole” (Armstrong v. United States, 354 U.S. 40, 49; 80 S. Ct. 1563 [1960]). But in the case of SGD, this rationale for compensation *contradicts* ethical arguments for environmental justice. As the Denton case highlights, many residents bear the burdens of drilling and do not share in the benefits.

It is also noteworthy that takings and vested rights issues largely speak to the legal rights of SGD's main beneficiaries, mineral owners, and less to the rights of those who experience the majority of negative side effects. Due process issues complicate the environmental justice story of SGD in communities and although several cases decided by the U.S. and Texas Supreme Courts provide insight into regulatory takings discussions (see e.g. McGinley 2004; King and Bryan 2004; Riley, 2007; Welch, 2012), there remains much ambiguity about what would constitute a regulatory takings in an SGD community (Welch, 2012).

The legal murkiness of urban SGD and municipal authority to regulate it adds to the uniqueness of this land-use activity; it also offers an entry point for the environmental justice perspective presented in this study. Specifically, because it remains unclear which municipal regulations would constitute a regulatory takings, local governments should err on the side of protecting the health, safety and welfare of those most at risk and simultaneously disenfranchised from most SGD decision-making processes.

7. Conclusion

From the standpoint of environmental justice, the ideal distribution of the costs and benefits of SGD in local communities would have those who bear the greatest environmental and health risks receiving the most financial benefits. Likewise, the ideal participatory scheme would have decision-making power regarding whether and how to develop shale gas be proportionate to exposure to environmental and health risks. In short, those paying the highest costs should get a fair share of the benefits and those facing the greatest risks should have a fair say in decision making.

The City of Denton has distributive and participatory schemas that little resemble environmental justice ideals. The primary beneficiaries of SGD in Denton are non-local mineral owners who comprise at least 61.4% of all mineral owners, receive at least 68% of the value, and, because of their distance from drilling activities, experience none of the costs associated with SGD in Denton. Entities with Denton mailing addresses also benefit from Denton's minerals, particularly the City of Denton and several family trusts, and individual Denton homeowners receive 6.3% of the total value held by mineral owners (or 1% of the total value including operator shares). Conversely, Denton's non-mineral owning residents receive no direct financial benefits, and very few indirect benefits, and are exposed to all the burdens and potential health risks because of their proximity to gas wells. In addition to these distributional inequities, there are questions about power structures and participation in Denton's SGD decision-making processes.

⁴ “Taking of property without just compensation is a violation of the 5th Amendment, as applied to the states through the 14th Amendment of the United States Constitution, and article I, §17 of the Texas Constitution” (King and Bryan, 2004, 10).

Distribution of financial benefits and participation in decisions are governed, not by exposure to harms, but by the severance of property estates, and the arbitrary (from the point of view of justice) political economic histories of land transactions that have determined the patchwork of mineral and surface ownership in the city. As a result, Denton's city government is left to try to empower non-mineral owners who ought to have a greater say in decisions. Such political enfranchisement by municipal governments is fraught, however, by the limited and contested nature of their powers. This is especially true in Texas, where the State has a storied history of promoting a very powerful oil and gas industry.

Furthermore, the role of Denton's city government is complicated by the fact that the City also gains financially from SGD. These financial benefits are distributed to the residents of Denton in various ways, and it could be argued that these constitute a form of compensation for those who are harmed by SGD. However, the City's investments are not targeted specifically at residents who, by virtue of their proximity to gas wells, are exposed to greater health risks (e.g., residents who live <0.5 miles from gas wells). Thus one potential policy implication for SGD communities would be to establish a fund that redistributes revenues directly to non-mineral-owning residents living in close proximity to gas wells (Briggle, 2014).

Vested rights and subsequent housing developments are other concerns for SGD communities. As Ottinger (2013, 256) notes, “Any process affording community members a role as informed participants in decision making must also confront the facts that relevant information may simply not exist, that it may by its very nature be inaccessible at the time decisions must be made, and that it may undergo consequential changes during the period of time over which a policy decision or act of consent will expose people to hazards.” Ordinances that are subject to continual revision would allow SGD communities to address the problem of vested rights that are incompatible with scientific advancement. As well, residents are often not adequately informed about the status of mineral ownership, the existence of gas well pad sites, the likelihood of future SGD activity, or the environmental and health risks associated with fracking. Therefore, policies aimed at increasing citizen participation in SGD decision-making need to provide new homebuyers and renters with appropriate information in order for them to fully consent to risks.

In the wake of the fracking ban in Denton, the Texas Oil and Gas Association and Texas' General Land Office sued the city (Heinkel-Wolfe, 2014). Their argument was essentially that municipalities do not have the jurisdictional authority to make such a sweeping condemnation of a mineral extraction process supposedly regulated at the state level. In other words, state authority trumps or preempts local authority. Regardless of how the specifics of this case turn out, our analysis suggests that securing both distributive and participatory justice requires strong local control. Courts and state legislatures should preserve the regulatory powers of municipal governments, which serve as the lone voice of non-mineral owners in SGD decision making.

Acknowledgments

We thank three anonymous reviewers and Alexandra Ponette-González for constructive and insightful comments that much-improved the manuscript. This research was supported in part by NSF GRANT #1262521.

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