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The conundrum of combustible clean energy: Sweden's history of siting district heating smokestacks in residential areas

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ABSTRACT

Communities may wish to source their energy locally to improve resilience in volatile energy markets, reduce greenhouse gas emissions, and support regional economies. Biomass and waste incineration offer one method that has been broadly adopted in European and Asian countries, particularly in combination with district heating systems. Yet, combustion and the placement of affiliated smokestacks often pose contentious planning obstacles for local communities. Learning from Sweden's example, this research maps where smokestacks are placed in relation to land uses, finding that residential areas comprise nearly 20% of the surrounding land uses within a quarter mile of district-heating associated smokestacks. The research concludes with policy-oriented recommendations for planning district heating.

1. Background: community heat and power

There are several reasons for localizing energy production including diversifying fuel sources for economic resilience (Kohl, 2008), reducing greenhouse gas (GHG) emissions (Lovins and Lovins, 1983; Li, 2005), and stimulating regional economies through new technology development and resource harvesting (Wei et al., 2010; Barrett et al., 2002; Lehtonen and Okkonen, 2013; Yi, 2014). More broadly, there are concerns over dwindling energy supplies, growing energy demands, limitations of fossil fuels, and threats from disruptive climate and political changes. Sudden oil price increases are linked to inflation, rising unemployment, higher interest rates and, as a consequence, high costs to society (Kohl, 2008). A move to local and renewable energy resources is expected to overcome such energy security challenges. In this respect, Kammen et al. (2006) reports that transitioning to a 20% national renewable energy portfolio by 2020 consisting of 85% biomass, 14% wind energy, 1% solar PV would create a total employment of 163,669 for the United States. Proponents are quick to point out that the US solar energy sector already employs more than the oil, natural gas and coal industries combined (DOE, 2017). Bioenergy, the main focus of this research, is currently the largest source of renewable energy and includes biomass and waste incineration, often dubbed “energy recovery” or Waste-to-Energy (WtE).

Indeed, the above reasons prompted many countries to sign the Kyoto Protocol in 1992. Even without the support of a national policy, cities and the state of California are following suit by adopting Climate Action Plans (Wheeler, 2008; Bassett and Shandas, 2010). As communities set goals, they may wish to look to examples of other large-scale successes.

Sweden provides an example of a country which has reduced GHG emissions per capita while re-localizing energy supply and growing the economy. Sweden became one of 32 countries to agree to cap their emissions as part of the United Nations Framework Convention on Climate Change (UNFCCC). Of these countries, twenty-three have been able to reduce their emissions in comparison with the base year of 1990 (UNFCCC, 2011), and Sweden is one of only nine countries that has achieved this reduction while steadily growing its economy (Brinkley, 2014). Sweden also stands out with the earliest and most dramatic GHG reductions (Brinkley, 2014). Carbon dioxide (CO_2) emissions alone fell by 60% since 1970. Until the late 1970s, Sweden sourced over 75% of its energy from imported oil. Today, biomass accounts for 23% of Sweden's energy supply at 129 TW h as compared to 189 TW h (34%) from nuclear fuel, the now dominant energy source (IEA, 2014; SEA, 2015). Through a combination of municipal and national-level policies, transformation of Sweden's energy sector spurred synergistic emissions reductions across waste, agriculture and the built environment (Brinkley, 2014). Though few countries consume more energy per capita than Sweden, the average Swede releases only 4.25 t of carbon dioxide per year into the atmosphere, compared with the EU average of 6.91 t and the US average of 16.15 t (IEA, 2014).

It is broadly acknowledged that Sweden achieved the above by establishing and expanding District Heating (DH) (UNCCC, 2013; Di Lucia and Ericsson, 2014; Werner, 2017). In DH, heat is produced centrally by water heated in a boiler and distributed through underground insulated pipes to heat exchangers at the point of use (Bouffaron and Koch, 2014). DH supplies both hot water and ambient heat. Over half of the

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Fig. 1. Top: Image of Göteborg Energi DH plant in the city center next to a popular pedestrian thoroughfare, apartment buildings, and high-end restaurants. Below: Image of DH plant and DH smokestacks on Stockholm skyline.

energy demand for buildings in the residential and service sectors in Sweden, as well as the United States, goes to heating space and water (SEA, 2015; EIA, 2015). Instead of every home and office operating an individual boiler, nearly 90% of apartment buildings and 17% of single family homes in Sweden are currently heated with DH (Di Lucia and Ericsson, 2014).

DH allowed Sweden to diversify its fuel mixture over a 40 year timespan by converting from traditional oil-fueled boilers to lower-emitting heat sources (Summerton, 1992; Palm, 2006; Magnusson, 2011; UNFCCC, 2013; Di Lucia and Ericsson, 2014; Werner, 2017). DH networks can be coupled with a variety of heat sources, such as heat generated as a byproduct from manufacturing, geothermal, biomass boilers, waste incineration, or combined-heat-and-power (CHP) plants to generate electricity, also called cogeneration (Lund et al., 2014). DH systems also allow for low-cost heat storage for during times of over-production from more volatile renewable energy sources, such as wind and solar (Lund, 2005; Connolly et al., 2014). The versatility of DH allowed Sweden's energy transformation to occur more rapidly than it might have occurred had Sweden needed to retrofit a mobile fleet or fuel sources for boilers in many individual buildings. Now, biofuels provide 40% of the fuel used in DH (Svensk Fjarrvarme, 2016).

For the above reasons, this research focuses on Sweden's DH systems, though such systems are broadly in use worldwide. DH systems are common in European countries such as Finland, Germany, Denmark, the Baltic countries and Eastern Europe (Euroheat and Power, 2007; UNEP, 2013) as well as in Russia and China (Werner, 2004). Because of their efficiency, the United Nations estimates that transition to DH systems, combined with energy efficiency measures, could result in a 30–50% reduction in primary energy consumption, thereby reducing CO_2 emissions by 58% in the energy sector by 2050 and allowing global temperature rises to stay within 2–3 °C (UNEP, 2013)

Yet, using biomass for energy most often means combustion- and requires a smokestack to be sited. Even oil-fueled boilers have affiliated smokestacks. Because heat loss occurs with longer pipelines, DH networks are more efficient when heat production and delivery points are proximate. As a result, incineration facilities and smokestacks are often located near the residential and commercial areas that make use of them. As communities localize energy infrastructure, they will need to consider where to place such facilities.

Many communities are squeamish about siting energy infrastructure in their neighborhood, particularly smokestacks, which have been previously associated with the release of particulate matter, resulting in asthma and other poor health outcomes for nearby communities (Lougheed, 2014). Davis and Henderson (2011) chart the changing American attitude to smokestacks from thinking of them as symbols of American progress during the industrial revolution to locally-unwanted land uses (LULUs) which prompt a Not-In-My-BackYard (NIMBY) response (Stradling and Thorsheim, 1999; Stradling, 1999). Similar complaints are often lodged against wind power and other renewable energies for disrupting viewsheds (Barry et al., 2008; Hirsh and Sovacool, 2013). In addition, there is a long history of siting waste and energy infrastructure in predominantly low-income and minority communities, resulting in health disparities and environmental burdens (Bullard, 2000).

While some European facilities hide the smokestacks behind