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A review of policy drivers and barriers for the use of anaerobic digestion in Europe, the United States and Australia

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ABSTRACT

Anaerobic digestion (AD) of biomass has become a common technology used in many European nations and is receiving increased attention in other nations. The chief attraction of AD is it generates renewable energy. Yet it also manages and treats organic waste, recycles key nutrients to soil, and can create local jobs; making AD an attractive technology to governments. In this paper we review the role government policy has played in promoting AD use and driving its growth in five developed nations studied; Australia, Denmark, Germany, the UK and USA. These nations were chosen for review as they provide a breadth of AD use with the number of AD plants in the aforementioned nations totaling 78, 114, 9545, 265, and 1497. This review looks to demonstrate and discuss policy mechanisms introduced by each nation that has helped drive AD use, and identify areas where policy can help overcome enduring challenges that face the AD industry. Focused discussion is given to waste management, climate change and energy security policies, and to financial incentives made available to AD installations. Analysis shows that the impact of performance based incentives targeted at small-medium capacity AD plants, less than 500 kW, have a significant positive correlation with the growth of AD use in the UK and Germany. The relatively new AD industry faces a number of barriers, which are also discussed, but with the help of supportive government policy for the technology, that considers the wide-ranging benefits of AD across government portfolios; investors will be more likely to show interest in the developing AD industry.

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Abbreviations: AD, Anaerobic digestion; AL, Alabama; AR, Arkansas; CA, California; CC, Climate change; CFI, Carbon farming initiative; CHP, Combined heat and power; DST, Decision support tool; EEG, Erneuerbare-Energien-Gesetz; EU, European Union; FiT, Feed-in-tariff; FL, Florida; GA, Georgia; GHG, Greenhouse gas; ID, Idaho; KY, Kentucky; LA, Louisiana; LCA, Life cycle assessment; LCC, Life cycle costing; LD, Landfill directive; LGC, Large-scale generation certificate; MS, Mississippi; MSW, Municipal solid waste; MTOE, Million tonnes of oil equivalent; NE, Nebraska; NSW, New South Wales; RE, Renewable energy; RET, Renewable energy target; ROC, Renewable obligation certificate; RPS, Renewable portfolio standard; RSD, Renewable sources directive; SC, South Carolina; TN, Tennessee; UK, United Kingdom; USA, United States of America; USD, United States Dollars ($); WFD, Waste framework directive; WRAP, Waste and resource action plan; WWTP, Wastewater treatment plant; WY, Wyoming

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1. Introduction

There is widespread potential for the adoption of anaerobic digestion (AD) installations wherever organic waste streams are produced. AD is a proven technology for treating organic waste streams, the energy and nutrient potential of which may otherwise be lost to non-anthropogenic processes. Wastewater treatment plants (WWTPs) have used AD worldwide for over 100 years to help treat organics in sewage [1,2]. Over the past 20 years, AD technology has proliferated in Europe, and to a lesser extent the USA, treating dairy, pig, chicken, and crop residues, as well as industrial and commercial wastes. These AD technologies are best defined as *on-farm AD* and *industrial AD*, respectively. More recently, AD has been proven to process and treat biowaste like food waste, cardboard food containers, grease trap residue and fats oils and grease [3–8]. Most wastes can be digested either as a mono-feedstock or co-digested with other organic streams [6–8]. Treating biowaste, agricultural and industrial organic wastes using AD recovers nutrients, reduces landfilling, and generates renewable bioenergy.

Despite the benefits of AD, its utilization has differed across the world [9–12]. Some nations have promoted AD through strong government policy, whilst others have provided little or limited impetus for its uptake. This review sets out to synthesize what government policies may have driven AD growth in the nations studied, with attention given to the impact of performance based financial incentives on AD use? Describe the context as to why policies have been implemented, and discuss how policies can assist in overcoming continuing barriers of AD use? The source of data used in this review was policy documents and industry assessments conducted or commissioned by government departments, multi-national organizations, and academic institutions across the five nations studied. Data for the compilation of each nations AD profile was obtained from industry, international organizations and government bodies, and personal correspondence with industry representatives.

The methodology followed to achieve the goals of this review comprise a case study analysis of Australia, Denmark, Germany, the United Kingdom (UK), and the United States of America (USA), within the case study; (i) each nation's use of AD is examined in terms of the number and type of AD plants as well as detailing the energy output and growth, (ii) key policies that affect AD growth are discussed within the context of each nation, including particular focus on financial incentives, (iii) the barriers to AD are examined with attention given to how policy may assist overcoming these barriers, and finally, (v) key improvements are proposed to AD policy and governance as well as suggesting further research that will help disseminate better information about AD.

The nations reviewed were chosen as to provide a varied range of AD adoption. Denmark, Germany and the UK were chosen as case studies as they are widely considered to be leaders in the use of AD and may provide a benchmark for achieving AD adoption [1,9,10,13]. The USA and Australia have been included as examples outside the European Union (EU), where AD is promoted, but where the number of plants built suggests a more modest AD growth has occurred. All nations studied have varied sociopolitical and geopolitical foundations and hence implement a broad spectrum of policies. Yet all nations are developed economies, members of the Organization for Economic Co-operation and Development, and have a sufficient quantity of data, allowing for a useful framework for comparison and discussion of policy experiences.

2. Profile of anaerobic digestion in jurisdictions studied

2.1. Denmark

Denmark is generally considered a pioneer of AD and the founder of centralized AD systems [13,14]. The industry grew from small community farm groups (the first plant was made from fiberglass for approximately €400 in the mid-1970s [14]). Yet, many reactors fluctuated in and out of use due to a dearth of technical and operational knowledge. In the 1990s, the Danish government became heavily involved in AD technology providing research grants investment funds and tax incentives [13,15]. District heating systems established in the 1980s were often built alongside AD community systems which provided a stable demand for AD heat bioenergy, [14].

The aforementioned conditions led to an increase in AD implementation. There were 12 AD plants in 1990 and by 2002 there were 57 [14]. The most recent count at the end of 2013 show 22 centralized and 60 on-farm AD reactors, as well as a significant number of WWTP with AD, (see Table 1). In order to meet future biogas and manure treatment targets it is estimated 40–50 new large scale AD plants will need to be built [12]. Currently most of the AD bioenergy generated is used as electricity (66%), and heat (20%), with the remainder flared [12]. The Danish government has recently signaled a prioritization to the upgrading of AD biogas to compressed natural gas for vehicle fuel, providing potential for future