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Incentivizing wood-based Fischer–Tropsch diesel through financial policy instruments: An economic assessment for Norway

Ryan M. Bright*, Anders H. Strømman

Industrial Ecology Programme, Department of Energy and Process Engineering, Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway

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ABSTRACT

The objective of this study is to evaluate a select set of financial incentive instruments that can be employed by the Norwegian government for encouraging early investment and production experience in wood-based Fischer–Tropsch diesel (FTD) technologies as a means to accelerate reductions in greenhouse gas emissions (GHG) stemming from road-based transport. We start by performing an economic analysis of FTD produced from Norwegian forest biomass at a pioneer commercial plant in Norway, followed with a cost growth analysis to estimate production costs after uncertainty in early plant performance and capital cost estimates are considered. Results after the cost growth analysis imply that the initial production cost estimates for a pioneer producer may be underestimated by up to 30%. Using the revised estimate we then assess, through scenarios, how various financial support mechanisms designed to encourage near-term investment would affect production costs over a range of uncertain future oil prices. For all policy scenarios considered, we evaluate trade-offs between the levels of public expenditure, or subsidy, and private investor profitability. When considering the net present value of the subsidy required to incentivize commercial investment during a future of low oil prices, we find that GHG mitigation via wood-FTD is likely to be considered cost-ineffective. However, should the government expect that mean oil prices in the coming two decades will hover between \$97 and 127/bbl, all the incentive policies considered would likely spur investment at net present values \leq \$-100/tonne-fossil-CO₂-equivalent avoided.

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1. Introduction

Second generation biofuel produced from woody biomass is expected to be an effective avenue for reducing fossil fuel consumption and greenhouse gas (GHG) emissions in road transport (Bright and Strømman, 2009; Bright and Strømman, 2010; Bright et al., 2010; Edwards et al., 2007; van Vliet et al., 2009; Zah et al., 2007). The Norwegian boreal forest offers a large, underutilized source of woody biomass (Bolkesjø et al., 2006; Gjølshjøl and Hobbelstad, 2009; Trømborg et al., 2008), and the Norwegian government is actively promoting the increased utilization of domestic forest resources for use as bioenergy (Trømborg and Leistad, 2009). While there are many application strategies which can efficaciously exploit the energy value of this resource – both within and outside the transport sector – the optimal strategy will vary depending on the primary policy objective(s) and/or sector(s) under target. This is demonstrated in (Joelsson and Gustavsson, 2010) and (Gustavsson et al., 2007) who show that oil use is more efficiently reduced in Sweden when

biomass replaces oil in stationary boilers rather than transport fuel produced in stand-alone plants, and similarly, that biomass usage outside the transportation sector may reduce GHG emissions more than biofuel in the transportation sector. It may also be the case that within the transport sector itself there are more effective uses of biomass resources for meeting GHG and energy reduction strategies. See for example (Ohlrogge et al., 2009; Campbell et al., 2009; Bright and Strømman, 2010). However, Grahn et al. (2009) show that industrialized nations cannot solely rely on reducing emissions from stationary sources and that biofuels become important for addressing options in transportation under scenarios involving stringent regionalized GHG emission caps, especially in the short- and medium-terms. This may be attributed to the difficulties in meeting near- and medium-term demands for rural road and heavy-duty freight transport in the absence of viable low-carbon alternatives.

In Norway, the government is aggressively targeting the road transport sector for the reduction of greenhouse gas emissions, and wood-based Fischer–Tropsch diesel (FTD) is viewed as an attractive part of the technological solution, particularly its use as a drop-in ready diesel substitute in rural and heavy-duty applications. Wood-FTD production technologies are soon scalable, with small-scale commercial production currently in the

* Corresponding author. Tel.: +47 73 59 89 72; fax: +47 73 59 89 43.
E-mail address: ryan.m.bright@ntnu.no (R.M. Bright).

start-up phases (Kiener, 2008) and large-scale commercial production expected to commence as early as 2012 (IEA/OECD, 2008; Rudloff, 2008). Plans for a commercial operation producing 270 million liters/year of FTD by 2016 are on the drawing board (Green Car Congress, 2008; Xynergo, 2008).

Yet further progress in technological development and improvement in certain processing steps are still required in order to make FTD production more cost-effective (IEA/OECD, 2008; van Vliet et al., 2009; Zhang, 2010) and attractive to today's investors. In addition to high capital costs (IEA/OECD, 2008; Londo et al., 2010; van Vliet et al., 2009), barriers to short-term deployment include higher project risk because such technologies have yet to be proven at the commercial scale (IEA/OECD, 2008; Londo et al., 2010). However, a need to deploy advanced biofuel technology that can significantly contribute to reductions in fossil fuel use and GHG emissions, particularly those stemming from road-based transport, necessitates the execution of sound support policies designed to accelerate their early commercialization. To the extent that reductions in fossil fuel use and GHG emissions are intended to be achieved by means of alternative transport fuel, a clear focus needs to be placed on those alternative fuels, like wood-based FTD, that reduce global warming emissions (OECD, 2008). Only when new technologies like FTD are deployed can their volumes be scaled up, since one gains operational experience which leads to steadily decreasing production costs (de Wit et al., 2010). In the US, for example, corn ethanol production costs have decreased 62% since the earliest commercial-scale producers first entered the market around 1975 (Hettinga et al., 2009). Thus in order to steepen the learning curve in the short-term, early commercialization of FTD technologies will likely require, in addition to current environmental sustainability standards and quota mandates for biofuels in EU biofuel regulation (European Commission, 2009), economic support policies designed to remove market barriers and incentivize investment into specific technologies (OECD, 2008; Sandén and Azar, 2005). Incentive-oriented policy approaches whose purpose is generating technological change are likely to be important parts of the policy portfolio for addressing certain environmental problems like global warming (Jaffe et al., 2005).

1.1. Objectives

Given that the government has the goal of deploying specific technologies as a means to reach the two overarching policy goals of reduced fossil fuel dependency and GHGs emissions in road transportation, our primary objective in this study is therefore to evaluate a select set of financial incentive instruments that can be employed for encouraging investment in wood-FTD plants in the near-term. In this study, we do not concern ourselves with estimating cost reductions over time resulting from technological learning. Our goal is to quantify levels of economic support needed in the short-term in order to accelerate the deployment of commercial FTD technologies. This predicates an understanding of the production costs likely to be borne by pioneer producers which is inclusive of the inherent technological risks affiliated with 1st-of-a-kind, or pioneer commercial FTD plants. We start by performing an economic analysis of a pioneer commercial plant design, relying on capital and operating cost estimates reported in publically available literature. These estimates make use of optimized operating parameters, mass and energy balances, and conversion efficiencies exhibited at laboratory and/or pilot/demonstration scale – combined with scale-dependent installation factors – for estimating direct and indirect capital investment costs and annual operating and maintenance (O&M) expenditures of a large scale commercial FTD plant.

History shows us that production costs upon start-up are often higher than original estimates for pioneer commercial energy and chemical process plants integrating new technologies and processes due to unforeseen capital cost growth and under-performance (Merrow et al., 1981; Deutmeyer, 2010). Misestimation of the capital costs and performance of innovative energy process plants like wood-FTD plants can create problems for government and industry in planning the development and commercialization of pioneering plants. We therefore derive new production cost estimates by performing a cost growth analysis based on our initial cost estimates of the pioneer case so that local decision makers can make better planning and investment decisions in the short-term. We follow this with a sensitivity analysis in order to observe changes in the new FTD product cost that are associated with variances in select underlying financial assumptions and economic performance parameters. This is succeeded by an analysis of various financing schemes and economic support mechanisms that would be required to encourage private investment in the short-term. Finally, we then use the new cost estimate inclusive of the added-risks elements associated with FTD produced at a pioneer commercial plant in order to evaluate GHG abatement costs of seven government deployment policy scenarios in light of uncertain future oil prices.

2. Technology description

We choose a FTD process developed by CHOREN™ Industries for our analysis because the same process will resemble commercial FTD production in Norway in the short term (Green Car Congress, 2008; Xynergo, 2008), and, from a technical maturity standpoint, it is one of the most advanced BTL processes in the world (IEA/OECD, 2008). The process is based on 3-step gasification of woody biomass followed by Fischer–Tropsch synthesis into synthetic diesel. The process is appealing because it is highly versatile to varying feedstock compositions; however, this requires some novel technologies that today are unproven commercially. A more detailed description and review of CHOREN™'s and other state-of-the-art FTD technologies can be found in Althapp et al. (2007), Blades et al. (2005), IEA/OECD (2008), van Vliet et al. (2009), Vogel et al. (2007), and Zhang (2010). The plant's processing steps can be aggregated into seven major block areas: *biomass treatment, gasification, gas cleaning, gas conditioning, Fischer–Tropsch synthesis, upgrading, and utilities.*

3. Methods and data

Commercial FTD production in Norway is based on CHOREN™ Industries' "Self-sufficient" process design operating on mixed forest residues. Material and energy balances for a commercial (500 MW_{th input}) FTD plant are based on design data for a 43 MW plant (β -plant) taking into account measured performance data for an existing 1 MW pilot plant (α -plant) operating in Freiberg, Germany, since 2003 (Althapp et al., 2007; Baitz et al., 2004). In our economic analysis, a discounted cash flow rate of return framework is employed to derive and compare a levelized FTD production cost at a pioneer plant in Norway both with and without cost growth analysis. A levelized production cost refers to the minimum price at which a unit of FTD must be sold for the project to break even, taking into account lifetime expenditures, revenues, capital investments, and return on investment. We henceforth refer to the "levelized" production cost as simply product cost; the pioneer case without cost growth analysis as our pioneer, starting point case ("Pioneer, SP"); and the case where

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