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Effects of changes in Italian bioenergy promotion schemes for agricultural biogas projects: Insights from a regional optimization model

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HIGHLIGHTS

- We review the evolution of agricultural biogas support schemes in Italy over last 20 years.
- A biogas supply chain optimization model which accounts for feed-in-tariffs is introduced.
- The model is applied to a regional case study under the two most recent support schemes.
- Incentives in force until 2013 caused homogenization towards maize based 999 kW_{el} plants.
- Wider, manure based supply chains feeding smaller plants are expected with future incentives.

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ABSTRACT

Italy has witnessed an extraordinary growth in biogas generation from livestock effluents and agricultural activities in the last few years as well as a severe isomorphic process, leading to a market dominance of 999 kW power plants owned by "entrepreneurial farms". Under the pressure of the economic crisis in the country, the Italian government has restructured renewable energy support schemes, introducing a new program in 2013. In this paper, the effects of the previous and current support schemes on the optimal plant size, feedstock mix and profitability were investigated by introducing a spatially explicit biogas supply chain optimization model, which accounts for different incentive structures. By applying the model to a regional case study, homogenization observed to date is recognized as a result of former incentive structures. Considerable reductions in local economic potentials for agricultural biogas power plants without external heat use, are estimated. New plants are likely to be manure-based and due to the lower energy density of such feedstock, wider supply chains are expected although optimal plant size will be smaller. The new support scheme will therefore most likely eliminate past distortions but also slow down investments in agricultural biogas plants.

1. Introduction

In the last few years, electricity generation from agricultural and landfill biogas in Europe has increased from approximately 17 TW h in 2006 (Eurobserv'er, 2008) to almost 36 TW h in 2011 (Eurobserv'er, 2012). In Italy, installed capacity and yearly electricity production increased by a factor of approximately 9 between 2007 and 2011 (Table 1).

Production values recently achieved in Italy are just a fraction of potentials: Tricase and Lombardi (2009) estimated that animal breeding sewage digestion alone could generate up to 3.6 TW h $year^{-1}$, which is approximately twice as much as *total* production levels in 2011.

In the near future, it would thus be technically feasible to expand agricultural biogas generation beyond current production levels. Whether expanding agricultural biogas generation would also be economically feasible depends largely on promotion schemes. In fact, several studies from different countries (e.g., Yiridoe et al., 2009; Gebrezgabher et al., 2010) confirm that, even considering co-benefits from cogenerated heat or digestate exploitation, power generation from agricultural biogas plants is profitable only when some form of incentive is available. Indeed, in the recent expansion of agricultural biogas in Italy, incentives were decisive.

1.1. The evolution of biogas support programs in Italy

The first incentives for electricity generation from agricultural biogas were introduced in Italy before the liberalization of energy markets with the resolution known as CIP6 (Provvedimento

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Nomenclature

Sets

T	feedstock type
S	technology size class
L	feasible locations (nodes)
A	feasible links

Subscripts

t	feedstock type
s	technology size class
i, j, k	feasible locations (nodes)
(i,j)	feasible links

Superscripts

AD	anaerobic digester
B	biomass (including energy crops and animal byproducts)
BG	biogas
BYP	byproducts from animal breeding
D	digestate
ECP	energy crops
FI	feed in tariff
GC	Green Certificates
H	heat
ICE	internal combustion engine
N	nitrogen
ORC	organic Rankine cycle
P	power
PLANT	energy conversion plant
TECH	generic conversion technology
disp_D	disposal (of digestate)
harv	harvesting
inv	capital investment
l_D	loading (of digestate)
lu_B	loading and unloading (of biomass)
maint	maintenance
lab	labour
purc_BYP	purchasing (of animal byproducts)
spread_D	spreading (of digestate)
tr_B	transport (of biomass)
tr_D	transport (of digestate)

Parameters

α	heat recovery fraction from *ICE* available for bottoming cycle (dimensionless)
δ^H	plant self-consumption of heat (dimensionless)
δ^P	plant self-consumption of electricity (dimensionless)
η_s^{ICE}	efficiency of internal combustion engine—*ICE* (dimensionless)
η^{ORC}	efficiency of bottoming organic Rankine cycle—*ORC* (dimensionless)
ρ_j	radius of the *j*th supply area [km]
τ	tortuosity factor (dimensionless)
I	annual interest rate (dimensionless)
M^{PLANT}	upper bound value for overall electric capacity of power plant (*ICE* and *ORC*) [kW]
N_t^{BYP}	nitrogen content in byproduct t [$kg_N\ t^{-1}$]
N^{ECP}	nitrogen content in energy crop [$kg_N\ t^{-1}$]
N_j^{max}	maximum permissible amount of nitrogen to be spread in j [$kg_N\ year^{-1}$]
SB_s	capacity upper bound of size class s [kW]
b^{TECH}	intercept of investment cost curve for technology *TECH* [€]
c^{spread_D}	unit cost of digestate spreading (referred to its nitrogen content) [€ kg_N^{-1}]
c^{harv_ECP}	unit cost of growing and harvesting energy crops [€ t^{-1}]
c^{ins_PLANT}	unit cost of insurance and warding [€ kW h^{-1}]
c^{l_D}	unit cost of digestate loading (referred to Nitrogen content) [€ kg_N^{-1}]
c^{lu_B}	unit cost of biomass loading and unloading [€ t^{-1}]
c^{maint_PLANT}	unit cost of plant maintenance [€ kW h^{-1}]
$c_s^{lab\_PLANT}$	labour cost coefficient depending on plant size class [€ $year^{-1}$]
$c_t^{purc\_BYP}$	purchase cost of different animal byproduct types [€ t^{-1}]
$c_t^{tr\_B}$	unit cost of transporting biomass [€ t^{-1} km^{-1}]
$c_t^{tr\_D}$	unit cost of transporting digestate [€ kg_N^{-1} km^{-1}]
$dist_{i,j}$	distance between *i*th and *j*th nodes [km]
d_t^{BYP}	digestate production rate for byproduct t (dimensionless)
d^{ECP}	digestate production rate for considered energy crop (dimensionless)
h^{PLANT}	annual operation hours of plants [h $year^{-1}$]
k^{BG}	average calorific value of biogas [kW h N m^{-3}]
m^{TECH}	slope of investment cost curve for generic technology *TECH* [€ kW^{-1}]
tar^{GC}	equivalent feed in tariff with Green Certificates under the 2009 support scheme [€ kW h^{-1}]
tar^{FI}	feed in tariff under the 2012 support scheme [€ kW h^{-1}]
tar_s^{BYP}	feed in tariff/Premium for animal byproducts based plants under the 2012 support scheme, depending on plant size class s [€ kW h^{-1}]
tar_s^{ECP}	feed in tariff/Premium for energy crops (maize silage) based plants under the 2012 incentive scheme, depending on plant size class s [€ kW h^{-1}]
vs_t^{BYP}	volatile solid content in animal byproducts, depending on type t (dimensionless)
vs^{ECP}	volatile solid content in energy crop (dimensionless)
$y_t^{BG\_BYP}$	biogas yield of animal byproducts, depending on type [N m^3 t^{-1} VS^{-1}]
y^{BG_ECP}	biogas yield of energy crop [N m^3 t^{-1} VS^{-1}]

Variables

BG_j	total annual biogas production at node j [N m^3 $year^{-1}$]
$C_j^{purc\_BYP}$	annual purchase cost of animal byproduct [€ $year^{-1}$]
$C_j^{harv\_ECP}$	annual production and harvesting costs of energy crop at node j [€ $year^{-1}$]
$C_j^{disp\_D}$	total annual cost of digestate disposal at node j [€ $year^{-1}$]
C_j^{inv}	annual equivalent cost of capital investment at node j [€ $year^{-1}$]
C_j^{lab}	total annual direct labor cost at site j [€ $year^{-1}$]
C_j^{main}	total annual maintenance cost at site j [€ $year^{-1}$]
$C_{(i,j,t)}^{tr\_B}$	total annual cost of transporting biomass of type t from node i to node j [€ $year^{-1}$]
$C_{(i,j)}^{tr\_D}$	total annual cost of transporting digestate of type t from node i to node j [€ $year^{-1}$]

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