Available online at www.sciencedirect.com
SCIENCE DIRECT®
Environmental Modelling & Software 20 (2005) 13–17
Environmental Modelling & Software
www.elsevier.com/locate/envsoft

Short communication

Techno-economic assessment of VOC-emission reduction strategies based on the ARGUS model

J. Geldermann*, O. Rentz

French-German Institute for Environmental Research (DFIU/IFARE), University of Karlsruhe (TH), D-76187 Karlsruhe, Germany

Received 29 October 2003; received in revised form 3 March 2004; accepted 2 April 2004

Abstract

Volatile organic compounds (VOC) are subject to several international environmental regulations such as the UNECE Gothenburg Protocol (1999) and the corresponding European NEC-Directive (on national emission ceilings for SO_2, NO_x, VOC and NH_3; 2001/81/EC). The mass flow optimization model ARGUS is proposed as a bottom-up approach for the elaboration of cost-effective VOC emission reduction strategies on a national and regional level. Various scenarios reflecting different time delays and pathways for the implementation of the emission reduction targets can be considered. The application of ARGUS is demonstrated for the sector of metal degreasing in Austria.

Keywords: Linear optimization; Cost curves; Volatile organic compounds; Emission reduction strategies; Technology assessment

Software availability
Name of Software: ARGUS
Developers: DFIU/IFARE
Contact Address: DFIU/IFARE, University of Karlsruhe, Hertzstr. 16, D-76187 Karlsruhe, Germany
Tel.: +49-721-608-4583
Fax: +49-721-758909
Email: jutta.geldermann@wiwi.uni-karlsruhe.de
Availability: In-house software for use in research and consultancy projects.

1. Introduction

Volatile organic compounds (VOC) are main contributors to environmental issues such as ground-level ozone, and are therefore subject to several international environmental regulations. Currently, the European Member States are developing programmes that set down specific measures to further reduce emissions of major air pollutants by 2010, in order to comply with the national emission ceilings (NEC) for SO_2, NO_x, VOC and NH_3 established by the European Directive 2001/81/EC. These programmes are an important step towards meeting the critical loads for acidification, eutrophication and ground-level ozone simultaneously in Europe, as negotiated in the Gothenburg Protocol under the UNECE Convention on Long-range Transboundary Air Pollution.

This 'multi-pollutant and multi-effect' Protocol sets limit values for specific emission sources (e.g. combustion plants, electricity production, dry cleaning, cars and lorries) and requires the application of best available techniques. VOC emissions from such products as paints and aerosols must also be cut. Finally, farmers will be required to take specific measures to control ammonia emissions.

The actual realization of national emission reduction strategies should be as cost-efficient as possible. Therefore, the aggregated results of integrated assessment models used for international emission controls (such as the Regional Air Pollution Information and Simulation (RAINS) model; Alcamo et al., 1990; Cofala et al., 2000), must be accompanied by bottom-up analyses, in

* Corresponding author. Tel.: +49-721-608-4583; fax: +49-721-758909.
E-mail address: jutta.geldermann@wiwi.uni-karlsruhe.de (J. Geldermann).

1364-8152/$ - see front matter
doi:10.1016/j.envsoft.2004.04.001

order to provide guidance for the affected industrial sectors in each specific country.

Models for the determination of national cost functions, such as ARGUS, PERSEUS, RAINS, MARKAL or others, take into account full sets of emission reduction options, including structural options related to changes in sectoral activities and production technologies (for an overview, cf. Hordijk and Kroeze, 1997; Makowski, 2000). They provide the 'cost optimal' evolution of the production system (production technologies and abatement options in place) over a given planning horizon, which in turn allows the realization of emission reduction ceilings and the supply of demand for products or services specified exogenously on the sectoral level. Fig. 1 gives an example of such cost curves/functions.

While several models for the elaboration of emission reduction strategies for CO_2, SO_2 and NO_x are in use, the ARGUS model (allocation module for a computer-aided generation of environmental strategies for emissions), based on linear programming, is one of the few that investigates VOC emissions from approximately 40 industrial sectors.

2. Methodological background of ARGUS

ARGUS is based on a detailed representation of all relevant stationary VOC emission sources and the corresponding applicable emission reduction options. It takes into account the mass flows that are generated by the considered industrial sectors, and includes for instance general solvent use, the chemical industry, refineries, fuel extraction and distribution, stationary combustion and many others, according to CORINAIR (Rentz et al., 1999a). The optimization criterion is the minimization of the sum of the discounted costs over the considered planning horizon. Emission sources and abatement options are described in terms of reference installations defined by the UN/ECE Task Forces on abatement options/techniques for VOC (Rentz et al., 1999b; Geldermann and Rentz, 2004). Roughly 2000 emission relevant processes and 1500 mass flows are modelled, not only including the current state of the considered industrial sectors, but also a wide range of best available techniques. The input data are structured in technological and in country data sheets.

- *Technological data sheets* specify the emission factor $e_{s,i,j}$, the investment $I_{s,i,j}$, and the operating costs $OC_{s,i,j}$ of an emission reduction option j applicable to a reference installation i of sector s.
- In contrast, the country data sheets are used to characterize the time dependent and country specific structure of emission sources in terms of the share of the different reference installations $x_{s,i,t}$ of total sectoral activities $A_{s,t}$ (market shares in sector s in year t) and the implementation rate $y_{s,i,j,t}$ of the emission reduction options (share of option (s,i,j) of the sectoral activity of reference installation (s,i) in year t).

This data distinction allows broad applicability in different countries because the technological data can be adjusted to current needs. In general, most of the necessary modifications deal with country specific data.

The model determines the evolution of the structure of emission sources and abatement options for the planning horizon. The optimization variables are the implementation shares $y_{s,i,j,t}$ of the different emission reduction options. The target function G is the sum of the discounted costs within the planning horizon:

$$G = \sum_s \sum_t \sum_i \sum_j \alpha_t \left(\tilde{I}_{s,i,j} \Delta Q_{s,i,j,t} + \tilde{O}C_{s,i,j} P_{s,i,j,t} \right) \qquad (1)$$

whereby the rate for the calculation of the investment dependent costs α_t includes, for example, the rate of depreciation, capital costs, repair and maintenance and can vary for each considered year t. The first term within brackets denotes the investment-related expenditures due to an increase $\Delta Q_{s,i,j,t}$ of the capacity of emission reduction option (s,i,j) in the year t. $\tilde{I}_{s,i,j}$ is the annualized specific investment per unit of capacity of option (s,i,j). The second term represents the operating costs of option (s,i,j), which is obtained by multiplying the annual production $P_{s,i,j,t}$ of installations equipped with this option by the specific annual costs per unit of activity $\tilde{O}C_{s,i,j}$. All these parameters can be expressed as a function of the optimization variables and the parameters specified in the technological and country data sheets.

Thus, the decision (optimization) variables are the capacities of the implemented production or emission

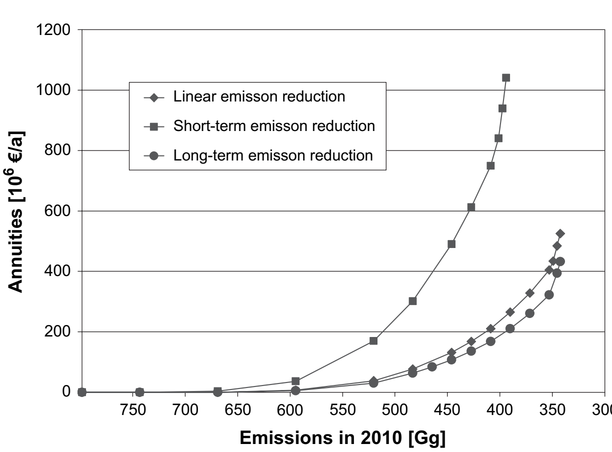

Fig. 1. Costs functions for different scenarios.