Renewable and Sustainable Energy Reviews 65 (2016) 676–684

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Complex biofuels related scenarios generated by qualitative reasoning under severe information shortages: A review

Mirko Dohnal

Brno University of Technology, Faculty of Business and Management, Kolejni 2906/4, 612 00 Brno, Czech Republic

ARTICLE INFO

Article history:
Received 14 December 2015
Received in revised form
8 June 2016
Accepted 5 July 2016

Keywords:
Qualitative model
Qualitative reasoning
Biofuel
Complex biofuel related model

ABSTRACT

There is a broad spectrum of BR (Biofuel Related) models. However the models are highly specific. Such models cannot flexibly support complex decision making activities to identify feasible trade-offs among many objective functions. They represent just one point of view; e.g. engineering, company economics. Therefore CBRMs (Complex Biofuel Related Model) are studied in this paper. CBRMs must cover additional aspects, e.g. macroeconomic, ecology, sociology and politics. Such models are inevitably unique, partially subjective, inconsistent, vague and multidimensional. AI (Artificial Intelligence) has developed a number of tools to solve such problems. Qualitative reasoning is one of them. It is based on the least information intensive quantifiers i.e. trends. There are just three trend / qualitative values: *plus/increasing; zero/constant; negative/decreasing*. There are many CBRM items related to soft aspects e.g. politics, taxation etc. which cannot be quantified by numbers. They are too vague. For example – *if the political/sociological sensitivity of land ownership is increasing then the cost of biofuels is increasing*. Such verbal knowledge item cannot be incorporated into a traditional numerical model. The paper describes developments of CBRMs based on expert knowledge and common sense. A consensus among experts is often not reached because of substantial subjectivity of experts' knowledge. A qualitative intersection of CBRMs developed by several experts is simple. The case study presents a model based on integration of 10 heuristics using 9 variables e.g. *Refinery Capacity, Cost of Biofuel Production, and Biofuel Demand*. The result is represented by 13 scenarios. The paper is self-contained, no a prior knowledge of qualitative models is required.

Contents

E-mail address: dohnal@fbm.vutbr.cz

http://dx.doi.org/10.1016/j.rser.2016.07.029
1364-0321/

1. Introduction

Biofuels experts, especially at the very beginning of any complex decision, do not use mathematical models as the basic framework for their reasoning. Experts draw heavily on knowledge represented by common-sense [1,2]. Many knowledge BR items are available as verbal descriptions based on trends: plus/increasing; zero/constant; negative/decreasing. For example:

if the political/sociological sensitivity of land ownership is increasingmore and more rapidly then the biofuel production is decreasing more and more rapidly (1)

This verbal heuristic represents a function

$$Y = f(X) \tag{2}$$

where

X = political/sociological sensitivity of land ownership
Y = biofuel production

The function (1) has the shape No. 26, Fig. 1.

Six examples of quantifier-less pair wise trend relations are given in the .

All pair wise relations f(*X*, *Y*)=0 in Fig. 1 are trend relations, i.e. based just on *increasing, constant, decreasing,* see e.g. [3,4]. For example the relation No. 26 indicates that the relation *Y*=*f*(*X*):

- is decreasing, i.e. the first derivative is negative
- the decrease is more and more rapid, i.e. the second derivative is therefore negative.
- if $X = 0$ then $Y > 0$.

No quantitative values are required to describe the shapes given in Fig. 1.

Many BR functions are so poorly known that the second derivatives are not available. Two types pairwise relations SUP and

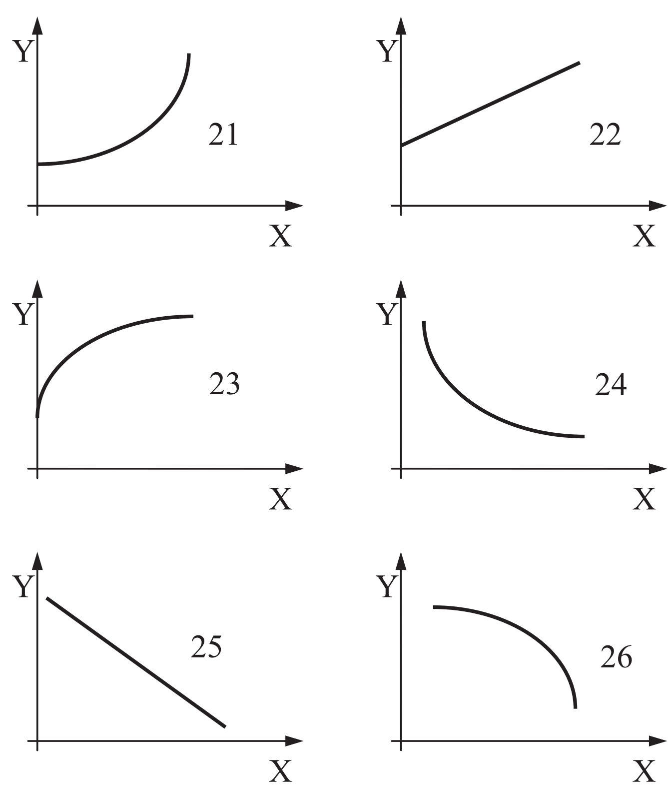

Fig. 1. Examples of qualitative pair wise relations.

RED based just on the first derivatives are considered in Fig. 1:

SUP: An increase in X has a SUPporting effect on Y *Shapes Nos.* 21–23
RED: An increase in X has a REDucing effect on Y *Shapes Nos.* 24 – 26 (3)

If the second derivatives are not known then the heuristic (1) is simplified:

if the political/sociological sensitivity of land ownership is increasing then the biofuel production is decreasing (4)

and can be formalized as follows, see (3):

political/sociological sensitivity of land ownership RED biofuel production (5)

The SUP and RED effects (3) are the least information intensive relations. It means that if it is not possible to specify them then nothing is known about the studied object.

There are roughly two types of BR models – CBRMs and EBRMs (Engineering BR Models). EBRMs can be analysed using the same models as are used in chemical engineering, see e.g. [5]. Such models are not studied in this paper. CBRMs are of inter-disciplinary nature [5,6].

2. Biofuel complexities

Soft sciences as e.g. macroeconomics, sociology are used to develop CBRMs [7,8]. The very nature of such models eliminates applications of traditional methods used for EBRMs, namely sets of algebraic and differential equations.

Deep knowledge items are such laws which reflect undisputed elements of the corresponding theory, e.g. the Newton laws are examples of deep knowledge items [9,10]. There are many different engineering BR deep knowledge items, e.g. some (sub)models of bioreactors. A deep knowledge item is usually available in a form of a differential or algebraic equation [11]. However, engineering BR deep knowledge items are not studied and used in this paper.

Unfortunately there are practically no non-engineering BR deep knowledge items, see e.g. (1, 4). This is the main reason why just networks of shallow knowledge items are studied in this paper. A shallow knowledge item is a heuristic or a result of a statistical analysis of observations and has usually (many) exceptions, see e.g. [12].

Shallow knowledge items have equations forms as well, for example exponential or polynomial relations. The choice of the equation is based on its suitability for statistical packages used to treat sets of observations [13,14] and has nothing in common with the deep knowledge equations. These aspects have been studied for long time already; see e.g. [15]. However, just recently newly developed computer programs can solve some multidimensional problems [16] based on quantifications-less models.

BR policies have impacts on broad spectrum of different problems of different natures, e.g. social, economic and ecological sustainability [17]. There are therefore many different factors, see e.g. [14]. It is obvious that different factors are differently difficult to quantify.

The following list covers selected important factors and does not cover the engineering parameters: