WORKING PAPER 528

Software for energy modelling: A theoretical basis for improvements in the user interface

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Thanks to Byung-Doo Choi whose work on critical reconstruction of Jurgen Habermas's ideas in the field of geography offers me important insights to investigate the philosophical background of existing energy models in the literature.

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Software for energy modelling: A theoretical basis for improvements in the user interface

1. Introduction

In this paper the work of Jurgen Habermas is used as a basis for a philosophical critique of the relationships between theory, knowledge and practice for a range of existing energy modelling styles. In particular, the author invoke Habermas's ideas regarding

(i) the three spheres of cognitive interest (i.e. technical, practical and emancipatory) and three levels of understanding of knowledge,

(ii) the construction of an 'ideal speech situation', and

(iii) the theory of communicative competence and action.

These are adopted as a basis for revealing shortcomings of a representative selection of existing computer-based energy modelling styles, and as a springboard for constructing a new theoretical approach. The following existing energy modelling styles are selected for scrutiny in this paper. Detail discussion of each of these can be found in Siu (1989: 81-169).

(1) Input-output (I-O) energy models such as

   a. Simple demand-driven I-O energy models (e.g. Common and McPherson (1982))

   b. Supply-driven I-O energy models (e.g. Giarratani (1976))

c. Disaggregated energy sector I-O models (e.g. Muller (1979))

d. Dynamic I-O energy models (e.g. Hoffmann and Jarass(1982))

e. I-O models embedded within other styles (e.g. Muller (1979))

(2) Econometric energy models such as

a. Linear econometric regression energy models (e.g. Smil and Kuz (1976))

b. Geometric regression energy models

c. Exponential regression energy models

d. Time-lagged energy models (e.g. Pearce and Westoby (1983))

(3) MEDEE models (Module d'Evolution de la Demand d'Energie) such as

a. Chateau and Lapillonne's MEDEE model (e.g. Chateau and Lapillonne (1978))

b. International Institute for Applied Systems Analysis's Energy System Program (IIASA's ESP) MEDEE-2 model (e.g. Hafele (1981), Khan and Holzl (1982), Keepin (1984))

c. Nijkamp and Tiemersma's MEDEE-2 model (e.g. Nijkamp and Tiemensma (1985))

(4) Systems dynamic energy models

a. Roberts' signed digraphs (e.g. Roberts (1971))

b. Allen's systems dynamics energy demand model (e.g. Allen et.al. (1985), Gould (1985))

The new energy modelling theory is to be built up from the simple but fundamental model constituents from which all energy model building components for different energy models can be generalised. It is argued that these important, essential energy modelling constituents interactively affect and react with each other, not only with respect to the levels of resolution of the 'physical' appearance of models (i.e. the level of detail of the model specifications, as reflected in their model equations), but more importantly, they are dependent upon a recognised, mutually-agreed communicative language which is in-built in a given energy modelling framework, to reveal the existence and functionality of the models. The new proposed energy modelling theory and approach is named the theory of 'communicative energy models'.

(1) Section 2 gives a brief summary of some of Habermas's theories. More detailed discussion of Habermas's ideas can be found in Choi (1987), Giddens (1982, 1984), Bernstein (1985, 1986), for instance.

(2) Section 3 presents a critique of Habermas's theories, particularly from the perspective of directly transferring them to the field of energy modelling. Relationships between Habermas's theories and the selected existing energy models, and to the two non-energy modelling frameworks (i.e. the cell-

space principle and the systems analysis) are also portrayed.

(3) Building on Habermas's work, a new conceptual framework for a general computer-based energy modelling approach is constructed in section 4. Contributions of this proposed theoretical framework to the field of energy modelling are also portrayed.

(4) In section 5 several practical strategies which might govern and guide any future development of the proposed theory are discussed.

2. Habermas's critical social theory

Most energy modellers would view the inner structures of energy models and other (non-energy) modelling frameworks to be synonymous with the 'physical' (modelling) structures of the models. (i.e. what types of model equations are they? Input-Output accounting equations? Or, differential equations?). However, the author argue here, in addition, that the inner structures of energy models can be viewed as having a different kind of role - that of achieving better understanding of the systems of interest being modelled. This alternative view is directly related to the theory, practice and concept of knowledge as widely discussed by philosophers (e.g. Plato, Aristotle, Kant, Hegel and Marx) and social-scientists (e.g. Gregory (1978), Hesse (1980, 1982), Bernstein (1976, 1983) and McCarthy (1984)).

The author find, in particular, the work of Habermas (1972, 1974, 1976, 1979 and 1984) to be a substantial basis for elaborating on weaknesses of existing energy models, and conceptualising a new, alternative approach for a theory and a framework for energy modelling. Selected aspects of the work of Habermas are reviewed and extended below towards this end.

This section gives brief reference to the work of Habermas. For details about the work of Habermas refer to Choi (1987). The aim is not only to provide a primary basis for the reader to comprehend Habermas's 'critical social theory'; but more importantly, to explain what constituents of Habermas's theories are later adopted and modified in subsequent sections to formulate a new energy modelling theory and framework.

2.1 Theory of cognitive interest

In his early work, Habermas (1972) identifies three spheres of knowledge: theoretical (Theoria), practical (Praxis) and productive (Poiesis) which can be recognised by the analysis of the three cognitive-knowledge interests: technical, practical and emancipatory. Correspondingly, three types of sciences are derived: the empirical-analytical, hermeneutic-historical, and critical-emancipatory sciences. All these sciences are grounded in one ontological dimension of human social existence: labour, interaction, or power. See Table 1.

According to Habermas, the concept of interest can be interpreted in either of the following ways:

(1) 'Cognitive interest' which mediates between the claim of contingent empirical fact and that of transcendental subjectivity.

(2) 'Knowledge-constitutive interest' which determines what constitutes the objects and types of knowledge, with a 'quasi-transcendental status' which conforms little to the distinction between the empirical and the transcendental.

In the theory of cognitive interest, the concept of self-reflection (or self-criticism) plays a central role and performs two functions: on the one hand, it denotes reflection upon the condition or potential ability of a subject as such; and, on the other hand, it denotes reflection upon unconsciously produced constraints to which a determinate subject succumbs in its process of self-reflection. These functions are referred to as 'rational reconstruction' and 'critical self-reflection', respectively, and become the central themes of Habermas's work on the theory of communicative action (i.e his critical social theory).

2.2 **Theory of communicative competence (universal pragmatics)**

Although the concept of self-reflection provides linkages between the tripartite relations between interest, knowledge and human activity, Habermas also

Table 1 A summary of Habermas's theory of cognitive interest - relating knowledge and human activity

Knowledge-cognitive interests	Types of sciences or knowledge		Ontological dimensions of human social existence
Technical (prediction & control)	empirical-analytic sciences	Theoretical (Theoria)	Labour
Practical (prudent understanding)	historical-hermeneutic sciences	Practical (Phronesis)	Interaction
Emancipatory (emancipation)	critical sciences	Productive (Poiesis)	Power (authority)

recognized that there was a need to examine these relations further, particularly in terms of the distinction between the process of constitution and that of justification of knowledge. This results in the development of a communicative competence theory (Habermas 1973).

The concept of communicative competence is concerned with reconstructing the general conditions of communication. This concept has characteristics parallel to the notion of linguistic competence. However, Habermas not only considers linguistic competence, but also the concept of communicative competence, consisting of basic qualifications of speech and symbolic interaction. This concept provides the means for the construction an ideal speech situation.

In the theory of communicative competence, Habermas argues that all claims of validity can be proven only in discourse (e.g. speech). Among several types of claims, the claims to truth are validated in 'theoretical discourse', and the claims to correctness or appropriateness of norms in 'practical discourse'. See Table 2.

According to Habermas, all discourse is oriented to the idea of a 'genuine consensus', which is formalized in the concept of 'an ideal speech situation'. The anticipation of an ideal form of discourse can be used as a normative standard for a critique of 'distorted

Table 2 The levels of theoretical-empirical and practical discourse (*)

	Theoretical-empricial discourse	Practical discourse
Conclusion	statement	percepts/evaluations
Controversial validity claim	truth	correctness/propriety
Demanded from opponent	explanations	justifications
Data	causes (of events) motives (of behaviour)	grounds
Warrant	empirical uniformities, hypothetical laws, etc.	behavioural/evaluative norms or principles
Backing	observations, results of surveys, factual accounts etc.	interpretations of needs (values), inferences, secondary implications,

Note:
(*) This table is extracted from Habermas (1973:243).

communication', to which people are likely to revert under coercion or under other types of adverse condition. The process of emancipation entails the transcendence of such systems of distorted communication. Habermas further explores the theory of communicative competence in terms of 'universal pragmatics'. The main task of universal pragmatics is to identify and reconstruct universal conditions of possible understanding (e.g. communication). In other words, the analysis of universal pragmatics is pursued in order to comprehend the elements and general conditions of understanding by reconstructing the rule systems which allow actors to communicate in any type of context.

2.3 **Theory of social evolution (developmental logic)**

In this theory, Habermas's previous view of action characterized in the distinction between labour and interaction is replaced and elaborated further by the distinction between purposive-rational and communicative action. In the former action, the actor is oriented to the realisation of an end while in the latter action the actor is oriented to reaching understanding. In other words, rationality of purposive action requires empirical knowledge of technical means and/or analytical consistency of choice between available means; while rationality of communicative action requires explanation of practical and normative value (Habermas 1979:117).

In relation to this distinction, Habermas also proposed a corresponding distinction between the 'institutional framework of a society' (which consists of norms that guide symbolic interaction) and subsystems in which primarily sets of purposive-rational actions are institutionalized (Habermas 1971:93-94). This typology has later developed into a differentiation between the 'inner nature' of a society (i.e. life-world) in which actions of a social group are coordinated through harmonizing action orientation (i.e. social integration) and 'outer nature' (i.e. self-regulative system) in which actions are coordinated through functional interconnections of action consequences (i.e. system integration). This differentiation entails the exchange between a society and its environment, which takes place in 'production' (appropriation on outer nature) and 'socialization' (appropriation on inner nature). These two distinctions in fact form the central themes of Habermas's 'theory of social evolution'. That is to say, through purposive-rational action and communicative action, human speech evolves in two separate but interrelated dimensions: namely, the development of the forces of production and the development normative structures of communicative interaction. Through the theory of social evolution, Habermas recognised four types of crisis tendencies in contemporary capitalism: Economic, Rationality,

Legitimation and Motivation crises. The former two crises are recognized as system crises and the latter two are identity crises. All four of them are interwoven into each other.

2.4 Theory of communicative action

From Habermas's point of view, these four types of crisis can be identified from two perspectives: that of a systems theory and that of an action theory (or an interpretative theory).

In his most recent work, Habermas develops the distinction between the rationality of goal-oriented (or cognitive-instrumental) action and the rationality of communicative action. The rationality of action is addressed in terms of its social consequences, i.e. the rationalization of society. Societal rationalisation is distinguished into two types: instrumental rationalisation of institutional forms geared to goal-oriented action, and rationalisation of the life world based on communicative rationality. The analytical differentiation between system and life world is the backbone of Habermas's theory of communicative action (and his theory of modernity). The clash between social systems of action having become independent from the shared life world and the life world itself as the ground for communicative rationality characterises the conflicts inherent in the development of capitalist societies. The result is the internal colonisation of

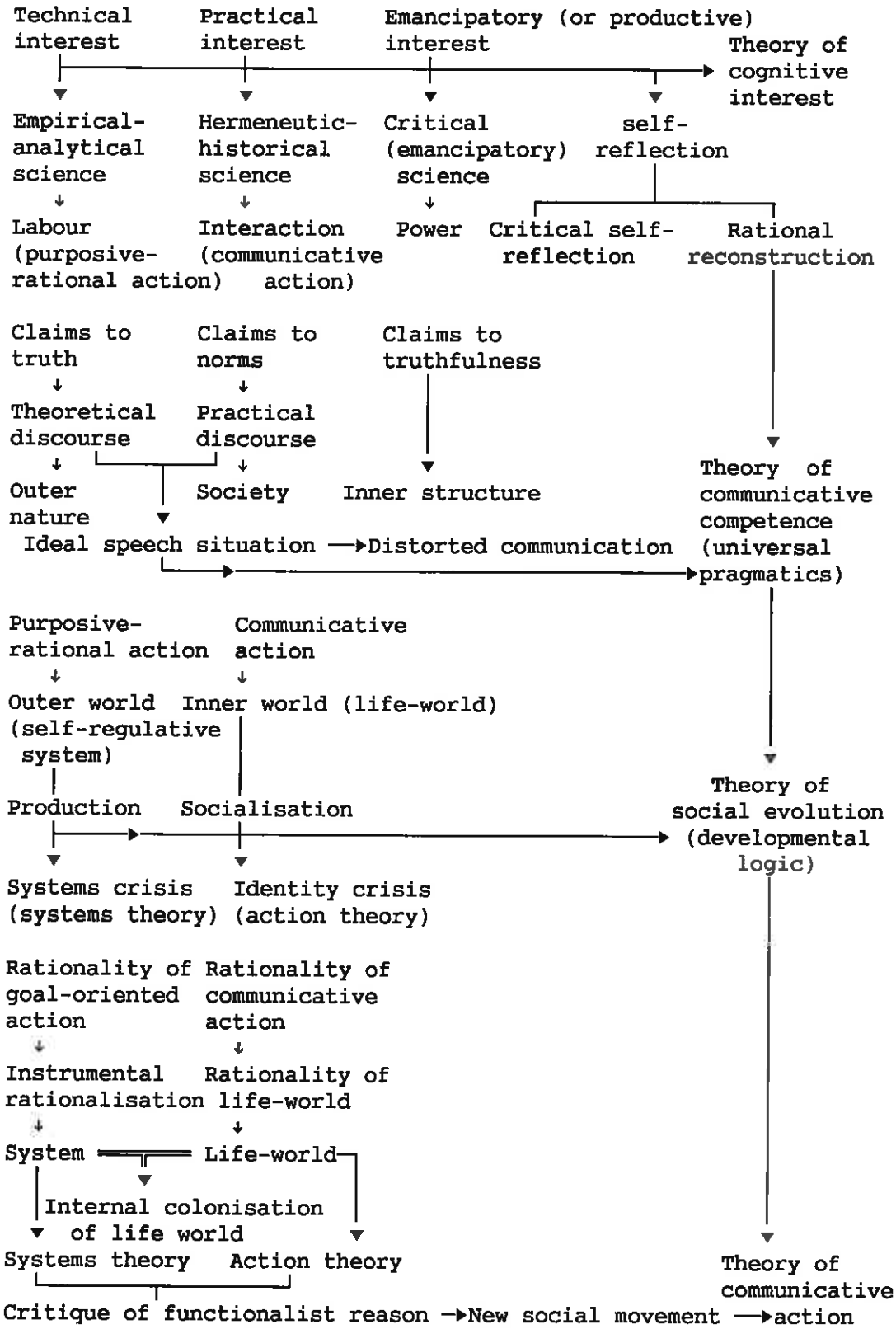
the life world. In this respect, Habermas further introduces the concept of the 'critique of functionalist reason' in the sense of the 'functional conditions of system reproduction' in the life world. According to Habermas, the critique of functionalist reason can be developed on the basis of a concept of society which integrates a theory of action and social systems theory. The tasks of critical theory today are to recover the colonised life world by functionalist reason. The new social movements, such as ecological and anti-nuclear movements, can be seen as concerned with protecting the life world against further colonisation.

For simplicity, the major concepts and their relations in Habermas's work over the past years are summarised in Figure 1.

3. A Critique of Habermas's theories in the perspective of energy modelling

Habermas's critical social theory was introduced to explain the evolution of societies from one stage to another through the analysis of social development, particularly for the individual (i.e. people). Habermas's ideas are rich in insight, but are not sufficient, nor beyond criticism or extension, from the point of view of developing and rationalising a new theoretical (conceptual) foundation for energy modelling. Since their development, Habermas's ideas have been criticised by many authors, including Thompson

Figure 1 A summary of the ideas of Habermas



(1981) and Giddens (1982). A critical examination of Habermas's theories from a social-geographical point of view can be found in Choi (1987:256-259). In this section, the author re-examines selected aspects of the theory of critical social theory with reference to the field of energy modelling.

3.1 A reconsideration of Habermas's critical social theory

Several problematic arguments are found in the presentation of Habermas's ideas. In general, they can be grouped into the following topics.

(1) Interpretation of language is predominant but contradictory throughout the studies of Habermas

Starting from his early study of a critique of cognitive interest, Habermas depended on 'language' as a medium to understand and identify the relationships between theory and practice. In the theory of cognitive interest, Habermas argued that three types of sciences (i.e the empirical-analytical, hermeneutic-historical and critical-emancipatory) correspond to three types of interest (i.e. the technical, practical and emancipatory) which are dependent on self-understanding of subjects (i.e people) and reciprocal understanding between each other via language. Further, in Habermas's theory of communicative competence and theory of communicative action, language becomes the

fundamental constituent of these theories. Although Habermas once argued that "language is also a medium of domination and social power ... language is also ideological" (Habermas:1977:360), in more recent work, he regards language as the single medium which serves mutual understanding. Also, it seems to the author that in his theories, Habermas's interpretation of language is confined to speech and discourse; however other interpretations of language are possible (e.g power, money). This argument stands out clearly especially from Habermas's theory of communicative competence and the ideal speech situation.

From the author's point of view, language should not be seen 'purely' as speech and discourse but should also consist of other elements such as norms, power, ideology and even technology. Also, Habermas's ideal speech situation is invariant to temporal-spatial and society dimensions. Language is not 'universal' at all, despite Habermas's suggestion. Language can be changed and, in fact, changes according to changes of time, space, society and even context.

In energy models, the commonly adopted formal and informal 'language' between energy modellers and analysts are mathematical equations and diagrams respectively. For example, input-output energy models are expressed in a set of accounting

equations while Roberts (1971, 1973 and 1975) adds estimated parameters to the weights of system components within a flow diagram (known as a digraph). In addition, as discussed in chapter 3, the formulations of IIASA's MEDEE-2 model have been critised as being full of institutional domination and ideology regardless of their appearance as simple accounting equations in the model specifications. In this respect, two issues are raised:

1.a Habermas's theory of cognitive interest seems to provide an explanation of the co-existence of different types of energy models within the field as each energy modeller is concerned with different types of interest (mostly the technical cognitive interest) at different levels of resolution. The given explanatory description of existing energy models in the energy modelling literature can be regarded as different interpretations and rationalisation of the purposive-instrumental actions or institutional constraints of modellers.

1.b In the field of energy, the concept of language used by energy modellers and analysts is seldom discussed and often completely neglected. This causes misunderstanding and unnecessary disputes. For example, the debate between Keepin and Hafele (Keepin, 1983).

Beyond the broad insights which Habermas's work can bring in identifying these issues, a clear distinction cannot be obtained: a direct transfer of Habermas's concept of language to the field of energy study proves insufficient. In the field of energy modelling, there is a need to formulate the concept of language being used by energy modellers and analysts in order to pursue mutual understanding. The aim must be to try and reach a situation of 'ideal speech' in energy modelling.

2. People (or actors) are the major subjects in the development of Habermas's theories, to the neglect of physical properties (e.g. natural reserves)

From all the theories of Habermas, it is noticed that his major interest is in the study of individuals (i.e. people) for explanation of the evolution of a society via the understanding of self-realization and self-regulating mechanisms in discourse. If these mechanisms fail, it causes misunderstanding, and leads to different types of crises. It seemed that the relationship between people and discourse (or speech) serves as a means to sustain domination and social power. Nevertheless, the author would argue that Habermas's thinking is insufficient and of limited value in the field of energy studies, because there is no consideration of physical properties (e.g. land,

natural resources) available for the use of the individuals in that society.

In the field of energy studies, the availability of natural reserves (e.g. oil, natural gas) for individuals in a society is the core focus of interest. It leads to the concepts of (re-) allocation and (re-)distribution, and economic and power domination, for example. As a consequence, energy models were introduced to serve as means to achieve better understanding of the relationship between the 'gift' from nature and the individuals in the societies. In this respect, the individual is not the only subject to be studied but also some 'exogenous' elements (e.g. physical properties, international or intersocietal relationship) available for the individuals in the societies. Habermas's ideas therefore have to be modified in order to be used in the field of energy studies.

3. Lack of spatial dimension in Habermas's theories

In his critical social theory, Habermas entirely neglects the spatial aspect of society. Habermas's conceptual work has proceeded as though human activity were conducted without a spatial element, as though human social life were spatially indifferent. According to Choi (1987:260), the lack of spatial dimension in Habermas's thinking is because he has been obsessed by 'reason' in a

transcendental (Kantian) manner. Habermas defends reason only by way of a critique of reason. Yet, Habermas does not realize that the enlightenment rationalism, which has developed on the basis of transcendental subjectivity in a sharp differentiation of external or sensuous knowledge, has a close relation to the decoupling process of reason and space.

As mentioned above, the availability of energy resources such as oil and natural gas is spatially dependent. They are highly dependent on the formation and the physical features of the area in which the individuals (or societies) are located. For this reason, the dimension of space (e.g. region, nation, world) are of great concern to energy modellers and analysts, and this element becomes one of the major components within all energy models in the literature. Space definitively has to be incorporated within Habermas's theory in order to be introduced to the field of energy study.

4. Insufficiency of the elements included in Habermas's theory of modernity.

In the theory of social evolution, Habermas distinguishes two dimensions of the rationalisation process of society: the empirical-analytic and practical-moral. Recently, he further distinguished these two dimensions into three socio-cultural

spheres of modern life i.e. science, morality and art. His differentiation of theoretical, practical and aesthetic rationality is regarded as a logical outcome of the evolutionary processes of the modern world. In particular, according to Habermas, the rationalisation of law, which is the precondition for the institutionalisation of rationalised economic and administrative systems, presupposes the differentiation of a sphere of formal law from the sphere of moral orientations. Yet, he is ambiguous in explaining the evolutionary mechanisms of these three cultural spheres.

According to Choi (1987:258), the empirical-analytical rationality (i.e. the theoretical) is institutionalized and accumulated in scientific enterprise. While agreeing with this statement (see, for example, the typical evidence from IIASA's MEDEE-2 models reviewed in Siu (1989)), the author also argue that the three basic elements of modernity - science, art and morality - are not sufficient to explain the modern state of the art within the field of energy studies, especially energy models. There are other elements which exert influence in the formulation of 'modernity' within the field of energy - technology and information - particularly the recent advance computer technology. This forms an important guideline governing the development of subsequent chapters in this thesis.

To sum up, the author find that Habermas' concepts of language and ideal speech situation, and, the theories of universal pragmatics, communicative competence and communicative action are interesting and seemed to provide fruitful insights in understanding deficiencies in the field of energy studies. However, to cope with different contexts in the field of energy modelling, Habermas's ideas have to be modified. A reconstruction of Habermas's thinking within the context of the field of energy is therefore proposed below in order to yield a new conceptual perspective for examining and analysing energy models. This new perspective forms a new theory within the field which will be explained in detailed in section 4. To substantiate this idea, it is necessary to re-visit the selected energy models and more general modelling frameworks from the perspective of Habermas's theories. This is done in the next section.

3.2 Relating existing energy modelling styles and general modelling frameworks to Habermas's cognitive interests

The selected energy modelling styles chosen for particular scrutiny in this chapter each correspond most closely to Habermas' 'technical' interest, as indicated in Table 3. More general modelling approaches, such as the cell-space principle as elaborated by Couclelis (1985), and the systems analysis approach, as elaborated by Wilson (1981), correspond more closely to Habermas'

Table 3 A classification scheme relating Habermas's three types of cognitive interests and energy models, and general modelling frameworks selected

Habermas's Types of interest	Habermas's Types of knowledge	Existing energy modelling styles and approaches	Model objectives
Technical	prediction & control	Selected energy models	purposive-goal oriented
Practical	prudent understanding (of systems of interest)	General approaches to modelling, such as cell-space principle* and systems analysis§	purposive-explication oriented
Productive	critical-emancipation	(not applicable)	explanatory-communication oriented

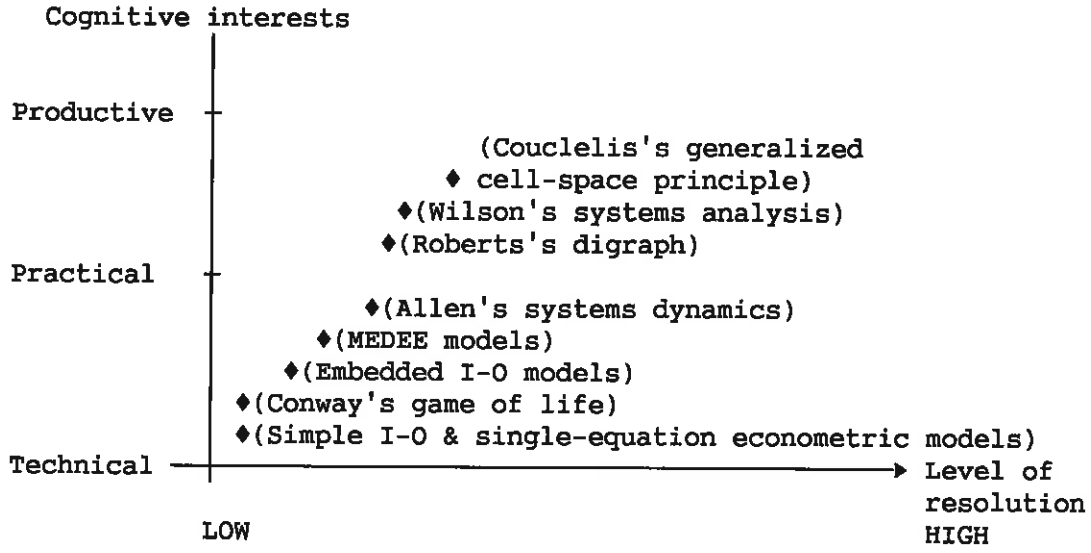
Notes:

* Couclelis (1985, 1986)
§ Wilson (1981)

'practical' interest. Both are, in theory, comparatively 'superior' to existing reviewed energy models, at least in the sense of being more concerned with ways of understanding system self-regulation and domination through self-realisation and self-regulative mechanisms (or modelling processes). In other words, these non-energy modelling frameworks aim at achieving prudent understanding of systems of interest in a communicative-interactive way. Nevertheless, when this type of modelling framework is being implemented at the application level, the derived applied models from these frameworks are also purposive-action orientated. Examples are Birkin (1986), Tobler (1979), Toffoli (1984). Figure 2 depicts a hierarchy of all these modelling styles and approaches at a more refined classification level.

The selected energy modelling styles are mostly used as purposive instruments of the energy modellers and analysts to compute and/or project the model results with given input values and pre-specified energy model equations. That is to say, the energy models themselves are used as a means and as an end. When the model is formulated (or the computer program is written for the model), this is predominant in governing the outcome of the model (e.g. restricted by the in-built, pre-specified model equations). At the same time, they are commonly used as predictive tools and control their own

Figure 2 A refined hierarchy of the selected energy models and general modelling frameworks under Habermas's theory of cognitive interest.



functions - demonstrating the perceptive conception adopted by the modeller in viewing the systems of interest. In principle, these models also pursue a prudent understanding of their modelled systems of interest. However, in practice, they have been used as an instrument to achieve rationalisation of the purposive-action of energy modellers and analysts.

For the more general modelling approaches (cell-space and systems analysis), in theory, their aims are explicative, achieving a prudent understanding of what constitutes the system of interest and how to interpret the model elements in an explicit (formal or informal) way. However, as commented earlier, their applied models tend to be purposive-action oriented.

3.3 Beyond existing energy modelling styles and existing general modelling frameworks

Based on the above arguments, it is important to ask what types of energy and non-energy models (or modelling frameworks) can be grouped under the category of productive cognitive interest? Alternatively, from Figure 2, why are there no models starting with or reaching the level of emancipatory (or productive) interest? Assuming that there is an absence of any emancipatory type of models, it may be wondered whether practical and/or practical interest type models are able to attain the (emancipatory) goal, given certain refinements? If so, what are the criteria for the

necessary refinements to those models? In addition, will the appearance of the emancipatory models help to solve the intellectual gap between the technical, practical and applied objectives? In the next section, the author attempt to answer these questions and eventually a new theoretical (conceptual) framework for energy modelling will be formulated and presented.

4. The development of a conceptual framework for a new energy modelling approach

4.1 Introduction

As already mentioned, the selected existing energy models seem to possess their own functionality and practicability and they cannot be replaced by one another; they stand on their own in the literature. The phenomenon of co-existence of these models is obvious but often neglected by people within the field of energy studies. If this has been taken for granted and energy researchers continuously introduce their own models, then the existing problem of fragmentation can only worsen. We believe that these undesirable consequences arise due to insufficient philosophical-theoretical exploration in analysing and understanding the perceptive, conceptual ideas of energy modellers and analysts, and the relations between energy modellers and the models they make.

A better understanding of the relationships between theory and practice can be gained from an examination of

Habermas's critical social theory within the context of the field of energy modelling. Habermas's thinking cannot be transferred without modification. Nevertheless, it yields important insights, and provides a useful springboard for constructing a more useful, communicative, energy modelling theory and framework.

4.2 A general theory of energy models

From Figure 2, it can be noticed that the two general modelling frameworks (i.e. the cell-space principle and that of systems analysis) are comparatively more advantageous than the selected applied energy models for providing a better understanding of system domination and self-regulative forces via communicative interaction. A prudent understanding of the modelled system of interest can be achieved and, at the same time, a high degree of transferability can be maintained, and ideas can be adopted at various levels of application in different fields of study. In this respect, these types of model are useful as stepping stones towards the formulation of a comprehensive (i.e. philosophical-theoretical, technical, practical and applied based) energy modelling framework and theory.

The problem is to identify the commonly adopted elements used by these two general modelling frameworks in governing their related applied models. Apart from the use of different terminologies (or 'labels'), the

author found that they can be summarised by the following categories, as a coarse but simple and easy to understand framework:

(1) Modelling environments

There are two types of modelling environments: internal and external system environment. The internal system environment is that which the system of interest is in. In other words, it is the environment that modellers are interested in. Conversely, the external system environment refers to the environment 'outside' the system of interest which exerts direct or indirect influence on the internal environment. If the system of interest is found in a self-contained environment (i.e. a closed system), there is no external environment; otherwise, for an open system, each system of interest will have a set of external environments which exert external influence on it.

(2) Model components

Model components are the constituents of the system of interest. They are also referred to as system variables. Each component has a specific (dominant or dependent) relation to each other component. Due to these relationships, they are often known as independent or dependent system components. In addition, they can be found in the internal or external system environments.

(3) Modelling functions

Each model component is assigned a set of function which can take any form (e.g. flow chart, mathematical or logical representation) to represent its relation to other model components.

(4) Model behaviour

Model behaviour is defined as the model outcomes of the system of interest with the given model functions and specified values corresponding to the model components.

Apparently, the proposed modelling framework is elementary and well-known. However, it is essential to appreciate that it can be regarded as a general theory of energy modelling within Habermas's practical interest perspective. The important element to support this general theory and to make it more explicitly introduced and understood is communication. Language is the core of this kind of communication. Based on this understanding, the author further attempt to formulate the proposed general energy modelling theory at an interactive-communication level.

4.3 The interactive-communicative energy modelling framework

As noticed in Figure 2, there is a lack of communication between each level of energy and non-energy models. The absence of a communicative system makes it impossible to establish linkages between each

model. At the same time, the (instrumental) achievement of a prudent understanding of the relationships between models and the inner life-world of the modellers is undermined. These undesirable effects are depicted in Figure 3.

It is understood that all the energy models and modelling frameworks are, in general, derived from the above proposed four basic modelling elements, regardless of what terminology each modeller and analyst adopts to rationalise their purposive-actions. Based on this general energy modelling theory, a further step would be to construct an environment or state that would provide a 'free communication', similar to Habermas's idea of 'ideal speech situation' and 'universal pragmatics', for each model at each level of cognitive interest (see Figure 4). In so doing, it is hoped to eradicate the unnecessary misunderstanding, and undermining effects, arising between modellers, models and users. In addition, this 'free speech environment' should offer a 'universal formal language' that can be used by each modeller for interpretation and communication. Consequently, the way is also paved for building an emancipatory type of model in the future.

The communicative framework is built on the realisation of the purposive-subjective interests of each individual energy modeller and analyst. This could only be done by explicitly expressing the 'physical'

Figure 3 Insufficient communicative system between modellers, models and users

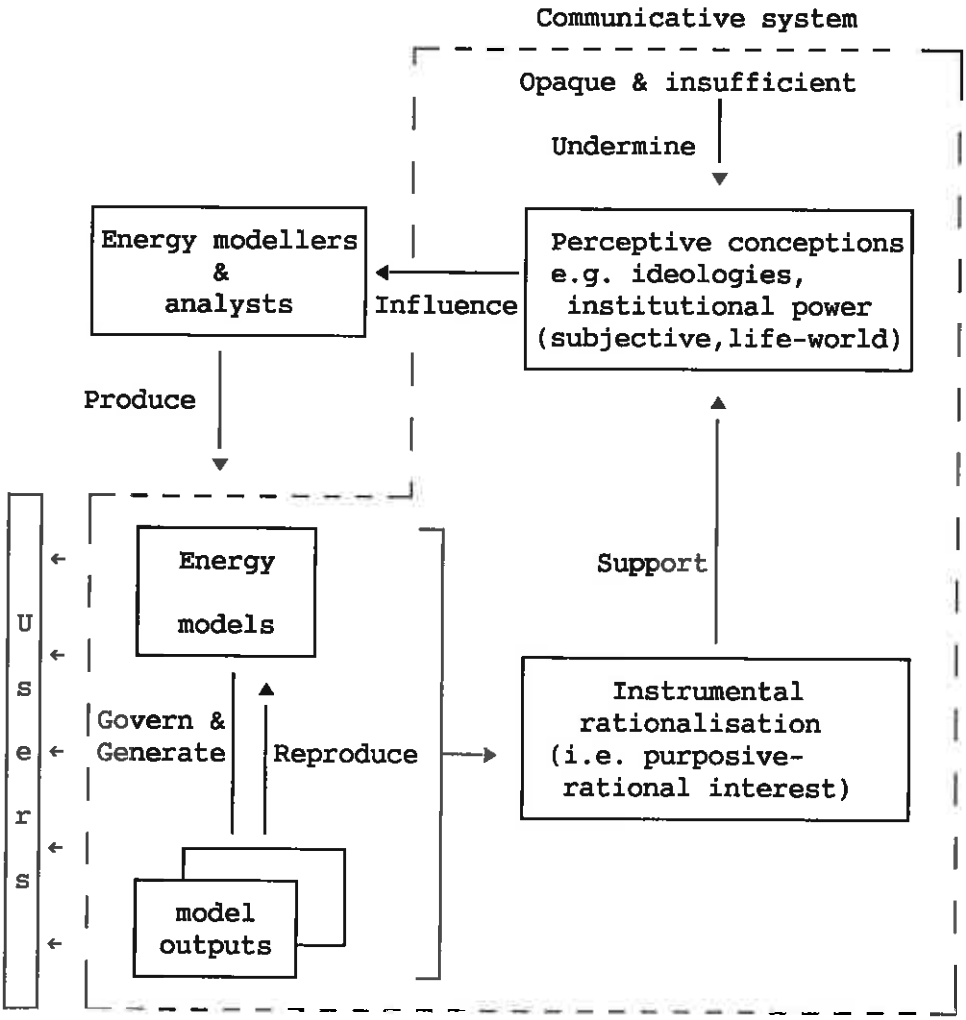
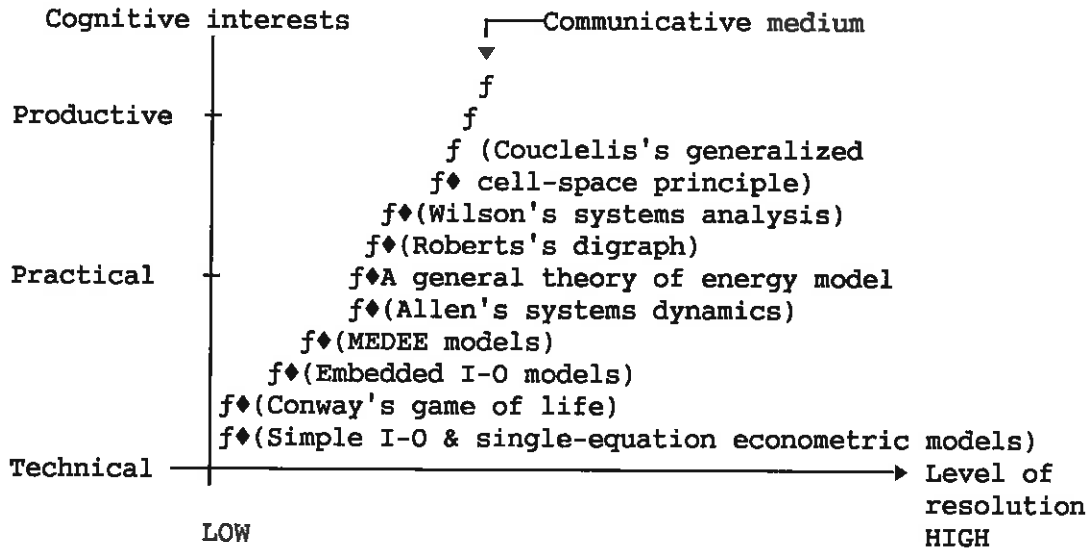


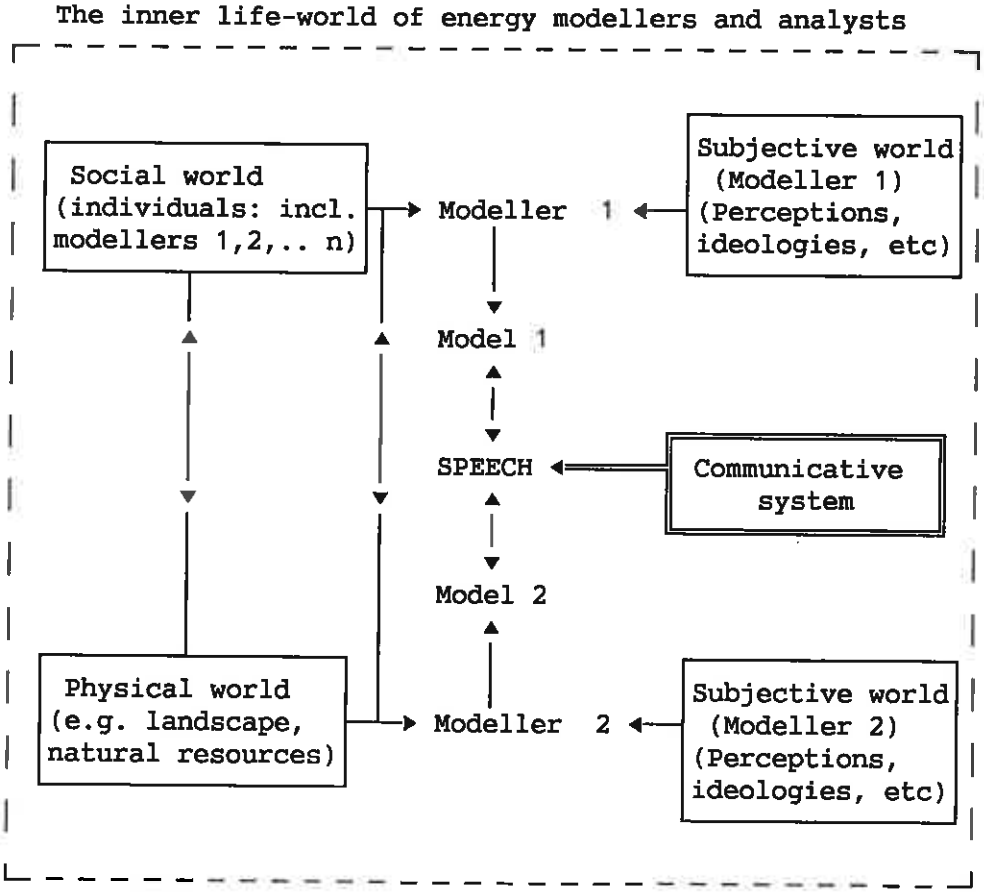
Figure 4 Formulation of a communicative system linking each model at each level of cognitive interests



structure of the energy models and the inner 'life-world' of modellers and analysts as portrayed in Figure 5.

Building this kind of communicative system cannot depend on the definition of language (i.e. speech or discourse) advocated by Habermas. It has been criticised in section 3.1. In the field of energy modelling, the commonly adopted formal language is that of mathematical equations. Also, as mentioned earlier, the recent modern trend is to translate these model equations into energy computer models. In this respect, the most useful and effective way is to construct a computer communicative system to allow free inflows and outflows of communicative interactions between modellers, models and users. In this computer communicative system, the disadvantages of Habermas's theories mentioned in section 3.1 can hopefully be eliminated (or, at least, that is the goal). This is because it should provide a 'world' with a universal 'computer-mediated' language for modellers, models and users to express and test their ideas freely. There should be no communication barriers. At the same time, it should allow consideration of spatial and non-spatial, and, temporal and non-temporal dimensions. In particular, this system should illustrate the above disagreements with the theory of modernity defined by Habermas.

Figure 5 Establishing a communicative interaction system to relate the physical properties of energy models and the inner 'life-world' of modellers



5. Conclusion

We have adopted a purely philosophical-theoretical perspective to examine the inner structures of selected energy modelling styles, and general modelling frameworks. Habermas's critique of theory and practice has been used to provide important and fruitful insights for constructing a new conceptual framework for a general computer-based energy modelling approach to fill an intellectual gap in the field of energy modelling. Software providing an initial realisation of the new conceptual approach proposed in this paper has been developed (Siu, 1989).

REFERENCES

Allen, P.M. (1982) "Evolution, modelling, and design in a complex world", Environment and Planning A, 1982, 9, 95-111.

Allen, P.M. (1983) "Self-organization and evolution in urban system", in Cities and regions as non-linear decision system, Ed. Crosby, R., AAAS Selected Symposium 77, Westview Printing, Boulder Co., 29-62.

Allen, P.M. Engelen, G. and Sanglier, M. (1984) "Self-organizing dynamic models of human systems", in From microscopic to macroscopic order, Ed. Frehland, E., Synergetics, Springer Verlag, Berlin, 22, 150-171.

Allen, P.M. and Paulre, B.E. (1985) "Guest editorial: new approaches in dynamical modelling", Environment and Planning B: Planning and Design, 12, 1-3.

Allen, P.M. and Sanglier, M. (1979) "A dynamic model of growth in a Central Place System", Geographical Analysis, July 1979, 11, 256-272.

Allen, P.M. and Sanglier, M. (1981) "Urban evolution, self-organizing, and decision making", Environment and Planning A, 1981, 13, 167-183.

Allen, P.M., Engelen, G. and Sanglier, M. (1984) "Self-organizing systems and the 'Laws of Socio-economic Geography'", The Brussels working papers on spatial analysis series A: Human Systems No. 4, Universite Libre de Bruxelles, Service Chimie Physique II, Campus Plaine: Code Postal 231, Boulevard du Triomphe, 1050 Brussels.

Allen, P.M., Sanglier, M., Engelen, G., and Boon, F. (1985) "Towards a new synthesis in the modelling of evolving complex systems", Environment and Planning B: Planning and Design, 1985, 12, 65-84.

Anderer, J., McDonald, A. and Nakicenovic, N. (1981) "Energy in a finite world: paths to a sustainable future", Ballinger Publishing Company, Cambridge.

Basile, P.S. (1980) "The IIASA set of energy models: its design and application", IIASA, RR-80-31, Laxenburg, Austria.

Beaumont, J.R. (1980) "Towards a conceptualization of evolution in environmental systems", School of Geography, Working Paper 282, The University of Leeds.

Berstein, R.J. (1985) "Introduction" in Habermas and Modernity, Polity Press, Cambridge, 1-32.

Bernstein, R.J. (1986) "Structuration as critical theory", Praxis International, 6, 235-249.

Birkin, M. and Clarke, M. (1986) "Comprehensive dynamic urban models integrating macro- and micro-approaches", School of Geography, Working Paper 439, The University of Leeds.

Birkin, M., Clarke, M. and Wilson, A.G. (1984) "Interacting fields: comprehensive models for the dynamical analysis of urban spatial structure", School of Geography, Working Paper 385, The University of Leeds.

Brody, A. and Carter, A.P. (1972) "Input-output techniques", North-Holland Publishing Company.

Calzonetti, F.J. and Solomon, B.D. (ed.) (1985) "Geography dimensions of energy", (The GeoJournal Library Series No.5), D. Reidel Publishing Company, Holland.

Chant, V.G. (1981) "Two global scenarios: the evolution of energy use and the economy to 2030", IIASA, RR-81-35, Laxenburg, Austria.

Chateau, B. (1975) "The methodology of long term forecasting: limitations of traditional methods and proposals", in Energy systems forecasting, planning and pricing, Eds. Cicchett, C.J. and Foell, W.K.

Chateau, B. and Lapillonne, B. (1978) "Long-term energy demand forecasting: a new approach", Energy Policy, 6, 140-157.

Chateau, B. and Lapillonne, B. (1979) "Long-term energy demand simulation", in Energy models for the European Community (E.C.), Ed. Strub, A., European Community Directorate-General XVII, Brussels, 120-128.

Choi, B.D. (1984) "Jurgen Habermas and Critical Theory for Human Geography", Lecture notes on MA course of Methodological Foundations of Human Geography.

Choi, B.D. (1987) "Space and social theory: a geographical critique and reconstruction", Ph.D. Thesis, School of Geography, Leeds University, England.

Common, M.S. and McPherson, P. (1982) "A note on energy requirement: calculations using the 1968 and 1974 UK input-output tables", Energy Policy, March, 1982, 42-48.

Couclelis, H. (1984) "Artifical intelligence in geography: conjectures on the shape of things to come", Department of Geography, University of California, Santa Barbara.

Couclelis, H. (1977) "Urban development models: towards a general theory", Ph. D. Thesis, University of Cambridge.

Couclelis, H. (1982) "Philosophy in the construction of geographic reality", in A search for common ground, Eds. Gould, P. and Olsson, G., Pion Ltd., Great Britain, 105-138.

Couclelis, H. (1983) "Some second thoughts about theory in the social sciences", Geographical Analysis, 15, 28-35.

Couclelis, H. (1984) "The notion of prior structure in urban modelling", Environment and Planning A, 1984, 16, 319-338.

Couclelis, H. (1985) "Cellular worlds: a framework for modelling micro-macro dynamics", Environment and Planning A, 1985, 17, 585-596.

Couclelis, H. (1986) "A theoretical framework for alternative models of spatial decision and behaviour", Annals of the Association of American Geographers, 76(1), 95-113.

Couclesis, H. and Golledge, R. (1983) "Analytic research, postivism, and behavioral geography", Annals of the Association of American Geographers, 73, 331-339.

Engelen, G. and Allen, P.M. (1985) "Modelling the spatial distribution of energy demand for the Province of Noord Holland. Towards an integrated approach", Institus Internationaux de Physique et de Chimie - and Service Chimie Physique II - Universite Libre de Bruxelles, Campus Plaine cp 231 - 1050 Brussels, Belgium. (Manuscript)

Engelen, G., Allen, P.M. and Fischer-Sanglier, M. (1983) "A spatial and dynamic model of an intra-urban system", Cahiers du Centre d'Etudes de Recherche Operationelle (C.E.R.O.), 25, no. 3-4, 241-266.

Farmer, D., Toffoli, T. and Wolfram, S. (1984) "Cellular automata: Proceedings of an inter-disciplinary workshop, Los Alamos, N.M., 7-11 March, 1983.", Physica D, 10 (1-2), (Special double issue).

Fedra, K. (1985) "The modelling process", International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria.

Giarratani, F. (1976) "Application of an interindustry supply model to energy issues", Environment and Planning A, 8, 447-454.

Gould, P. (1985) "A critique of dissipative structures in the human realm", The Pennsylvania State University, 306 Walker Building, University Park, PA 16802, U.S.A. (Manuscript)

Gould, P. (1979) "Signals in the noise", in Philosophy in geography, Eds. Gale, S. and Olsson, G., D. Reidel Publishing Company, 379-386.

Gould, P. and Olsson, G. (ed.) (1982) "A search for common ground", Pion Ltd., Great Britain.

Grenor, M. (ed.) (1979) "Methods and models for assessing energy resources", (First IIASA conference on energy resources, May 20-21, 1975.) IIASA Proceddings Series 5, Pergamon.

Griffin, J.M. and Steele, H.B. (1980) "Energy economics and policy", Academic Press, London.

Habermas, J. (1970) "On systematically distorted communication", Inquiry 13, 205-218.

Habermas, J. (1971) [1969] "Towards a rational society", translated by J.J. Shapiro, Heineman, London.

Habermas, J. (1972) [1968] "Knowledge and human interests", translated by J.J. Shapiro, Heineman, London.

Habermas, J. (1973) "Wahrheitstheorien" in Wirchlichkeit und Refleion, Ed. H. Farenbach (Neske, Pfullingen), 211-65.

Habermas, J. (1974) [1971] "Theory and practice", translated by J. Viertel, Heineman, London.

Habermas, J. (1976) [1973] "Legitimation crisis", translated by T. McCarthy, Heinemann, London.

Habermas, J. (1977) "A review of Gadamer's Truth and Method" in Understanding and Social Inquiry, Eds F. Dallmayr and T. McCarthy, Notre Dame University, Notre Dame, 335-363.

Habermas, J. (1979) [1976] "Communication and the evolution of society", translated by T. McCarthy, Heinemann, London.

Habermas, J. (1984) [1981] " The theory of communicative action; 1 reason and the rationalisation of society", translated by T. McCarthy, Heinemann, London.

Habermas, J. (1985) "A philosophical-political profile", (interview), New Left Review, 151, 75-105.

Hafele, W. (1981) "Energy in a finite world: a global system analysis", Ballinger Publishing Company, Cambridge.

Hafele, W. and Rogner, H.H. (1984) "A technical appraisal of the IIASA energy scenarios? A rebuttal", Policy Sciences, Dec. 1984, 17, No. 4, 341-366.

Hafele, W. (ed.) (1981) "Modelling of large-scale energy systems: proceedings of the IIASA/IFAC symposium on modelling of large-scale energy systems Feb. 25-29, 1980", IIASA Proceeding Series 12. Pergamon.

Hayes, B. (1984) "Computer recreations: the cellular automaton offers a model of the world and a world unto itself", Scientific American, 250(3), 12-21.

Hedley, D. (1986) "World energy: The facts and the future", Euromonitor Publication Ltd.

Hesse, M. (1980) "Revolutions and reconstructions in the philosophy of science", Harvester Press, Sussex.

Hesse, M. (1982) "Science and objectivity", in Habermas: Critical debates, Eds. J.B. Thompson and D. Held, Macmillan, London, 98-115.

Hitch, C.J. (1977) "Modelling energy-economy interactions: five approaches", Resources for the future, Washington, D.C.

Hoffann, L. and Jarass, L. (1982) "The impact of rising oil prices on oil importing developing countries and the scope for adjustment", Forschungsgesellschaft fur Alternative Technologien und Wirtschaftanalysen mbH (ATW).

Keepin, B. (1984) "A technical appraisal of the IIASA energy scenarios", Policy Sciences, 1984 (Nov.), 17, No. 3, 199-276.

Khan, A.M. and Holzl, A. (1982) "Evolution of future energy demands till 2030 in different world regions: an assessment made for the two IIASA scenarios", IIASA, RR-82-14, Laxenburg, Austria.

Kopelman, J.B. and Weaver, N.L. (1978) "Energy modelling as a tool for planning", Long Range Planning, 11, 25-33.

Kossov, V. (1970) "The theory of aggregration in input-output models", in Contributions to input-output analysis, Eds. Carter, A.P. and Brody, A., North-Holland Publishing Company, Amsterdam, 241-248.

Kydes, A.S. (et al.) (1983) "Energy modelling and simulation: IMACS Transactions on Scientific Computation 10th IMACS World Congress on Systems Simulation and Scientific Computation, Montreal, Canada, 8-13 August 1982, IV", North-Holland Publishing Company, Amsterdam.

Kydes, A.S., Minasi, M.J. and Hudson, E.A. (1983) "A new energy-economy system: macroeconomic feedbacks and linkages", in Energy modelling and simulation, Ed. Kydes, A.S., IMACS/North-Holland Publihsing Company, 49-66.

Lapillonne, B. (1976) "System analysis and scenario approach for detailed long range energy demand forecasting", IIASA, PP-76-10 (Professional Paper), Laxenburg, Austria.

Lapillonne, B. (1978) "MEDEE-2: a model for long-term energy demand evaluation", IIASA, RR-78-17, Laxenburg, Austria.

Lapillonne, B. and Chateau, B. (1979) "The MEDEE models for long term energy demand forecasting", in Strub, A. (ed.) Energy models for the European Community, European Community Directorate General XVII, Brussels, 329-342.

Leontief, W. (1966) "Multiregional input-output analysis", in Input-output economics, Ed. Leontief, W.,Oxford University Press, 223-257.

Leontief, W. (1966) "Input-output analysis", in Input-output economics, Ed. Leontief, W., Oxford University Press, 134-155.

Leontief, W. (1966) "Input-output economics", Oxford University Press.

Leontief, W. (1970) "The dynamic inverse", in Contributions to input-output analysis, Eds Carter, A.P. and Brody, A., North-Holland Publishing Company, Amsterdam, 17-46.

Leser, C.E.V. (1972) "Econometric techniques and problems", Griffin, London.

Lesuis, P., Muller, F. and Nijkamp, P. (1980) "An integrated policy model for energy-economic-environmental interactions", Regional Science and Urban Economics, 10, 343-370.

Lev, B. (ed.) (1983) "Energy models and studies", (Studies in management science and systems, 9) North-Holland Pub. Co.

Macgill, S.M. (1986) "Research policy and review 12. Evaluating a heritage of modelling styles", Environment and Planning A, 18, 1423-1446.

McCarthy, J. (1981) "Epistemological problems of artificial intelligence", in Readings in artificial intelligence, Eds. Weber, B.L. and Nilsson, N.J., Tioga Publishing Company, Palo alto, California, 459-465.

McDonald, A. (1981) "Energy in a finite world: executive summary", IIASA, Laxenburg, Austria.

Meier, P. (1984) "Lecture notes in economics and mathematical systems: Energy systems analysis for developing countries", Spring-Verlag, Berlin.

Muller, F. (1979) "Energy demand in the Netherlands 1972", Martinus Nijhoff Publishing, London, 101-127.

Neter, J., Wasserman, W. and Kunter, M.H. (1985) "Applied linear statistical models: regression, analysis of variance, and experimental design", Richard D. Irwin Inc., Illinois.

Nijkamp, P. and Tiemersma, D. (1985) "Spatially-oriented energy consumption scenarios: method and application to Holland", in Geography dimensions of energy, Eds. Calzonetti, F.J. and Solmon, B.D., D. Reidel Publishing Company, 299-323.

Nystuen, J.D. (1984) " comment on 'Artifical intelligence and its applicability to geographical problem solving' ", Professional Geographer, 36, No. 3, 1984, 358-359.

Ostrom, C.W. (1978) "Time series analysis - regression techniques", Sage University Paper Series, Sage Publications.

Pearce, D.W. and Westoby, R. (1983) "Energy and the European Community", in A.M. El-Agraa (ed.) Britain within the European Community (Macillan, London, 1983).

Roberts, F.S. (1971) "Signed digraph and the growing demand for energy", Environment and Planning A, 3, 395-410.

Roberts, F.S. (1973) "Building and analyzing an energy demand signed digraph", Environment and Planning A, 5, 199-221.

Roberts, F.S. (1975) "Weighted digraph models for the assessment of energy use and air pollution in transportation systems", Environment and Planning A, 7, 703-724.

Roberts, F.S. (ed.) (1976) "Energy: mathematics and models", (Proceedings of a SIMS Conference on energy held at Alta, Utah, July 7-11, 1975), Society for Industrial and Applied Mathematics, Pennsylvannia.

Siu, Y.L. (1989) "Energy-economic planning and assessment in developing countries; the design and exploration of an energy modelling approach", Ph.D. Thesis, School of Geography, Leeds University, England.

Siu, Y.L. (1989) "TEAM: A PC-based toolbox for energy-economic analysis and modelling", Computer Manual 31, School of Geography, Leeds University, England.

Smil, V. and Kuz, T. (1976) "European energy elasticities", Energy Policy, June 1981, 113-126.

Smith, T.R. (1984) "Artifical intelligence and its applicability to geographical problem solving", Professional Geographer, 36, No. 2, 1984, 147-158.

Smith, W. (1983) "Energy/Economy modelling: science or heuristics?" in Energy modelling and simulation, Eds. Kydes, A.S., IMACS/North-Holland Publishing Company, 3-12.

Tobler, W.R. (1979) "Cellular geography", in Philosophy in geography, Eds. Gale, S. and Olsson, G., 379-386.

Toffoli, T. (1984) "Cellular automata as an alternative to (rather than an approximation of) differential equations in modelling", Physica, 10-D, 117-127.

Ulph, A.M. (1980) "World energy models - a survey and critique", Energy Economics, Jan. 1980, 46-59.

Valavanis, V.S. (1959) "Econometrics", New York: McGraw-Hill.

Van Koevering, T.E. and Sell, N.J. (1986) "Energy: a conceptual approach", Prentice-Hall Inc., Englewood Cliffs, New Jersey 07632, U.S.A.

Weizenbaum, J. (1984) "Computer power and human reason: from judgement to calculation", Penguin books.

Westoby, R. and Pearce, D. (1984) "Single equation models for the projection of energy demand in the U.K., 1954-1980.", Scottish Journal of Political Economy, 31, No. 3, Nov. 1984, 229-254.

Wierzbicki, A. and Young, P. (1981) "System and decision sciences at IIASA 1973-1980", IIASA, SR-81-3, Nov. 1981, Laxenburg, Austria.

Wilbanks, T.J. (1985) "Geography and energy: the quest for roles and missions", in Geographical dimensions of energy, Eds. Calzonetti, F.J. and Solomon, B.D., D. Reidel Publishing Company, 497-510.

Wilson, A.G. (1981) "Geography and the environment: systems analytical methods", John Wiley and Sons.

Wilson, A.G. (1981) "The formal basis of system analysis", in Geography and the environment: systems analytical methods, Ed. Wilson, A.G., Chapter 2, John Wiley & Sons.

Wilson, A.G. (1984) "Reticular research: Alan Wilson on the discipline of disciplines", Times Higher Education Supplement (THES), 20th July.

Wilson, A.G. (1985) "Research policy and review 3: raising the levels of ambition in research: some lessons from the journal", Environment and Planning A, 17, 465-470.

Wilson, A.G. (1985) "Useful philosophy", Working paper no. 437, School of Geography, The University of Leeds, Leeds, LS2 9JT.

Wynne, B. (1983) " Models, muddles and megapolicies: the IIASA energy study as an example of science for public policy", IIASA, WP-83-127, Dec. 1983, Laxenburg, Austria.

Wynne, B. (1984) "The institutional context of science, models, and policy: the IIASA energy study", Policy Sciences, 1984, 17, No. 3, 277-320.

Zeigler, B.P. (1976) "Valid model construction and simplication", in Theory of modelling and simulation, Eds. Zeigler, B.P., John Wiley and Sons, 306-317.

Zeigler, B.P. (1976) "Hierarchy of system specificatios", in Theory of modelling and simulation, Eds. Zeigler, B.P., John Wiley & Sons, 199-260.

Zeigler, B.P. (1976) "Simulation program verification and complexity", in Theory of modelling and simulation, Eds. Zeigler, B.P., John Wiley and Sons, 370-379.

Zeigler, B.P. (1976) " Theory of modelling and simulation ", John Wiley and Sons, Inc.