Title: Use of Decision Analysis Principles to Enhance Electricity Regulation

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INTRODUCTION

Nobody can deny that the development of the energy sector plays a significant role in the growth of any economy and that the electricity utility is perhaps the most vital cog in the wheel. Recognizing this, regulators have the responsibility to ensure that the electricity industry enhances economic welfare of a country and that the service continues to be available at affordable prices and reasonable standards to all members of society.

In making decisions regarding fuel mix, generation technology, rates and regulatory methods utilities and regulators have to wrestle with a number of conflicting issues. In many cases the economic objectives of the sector contradict social and environmental objectives which are just as important in the development of a community. Furthermore, a regulator has to consider the positions of many different stakeholders who often have diverging interests.

Notwithstanding these complexities, electricity utilities tend to make major decisions using mathematical models which are generally based on linear programming principles. These optimization techniques attempt to minimize continuous variables such as planning costs, and environmental emissions while maximizing reliability and safety. For example, in attempting to resolve the conflict of minimizing costs while maximizing reliability, the constraint that is generally employed is loss of load expectation (LOLE). This may be set at a value such as one day per year. The models may be used to determine order of

[1] The views expressed in this article are those of the author and should not be attributed to the Commission or any Commissioners.

dispatch and use of fuel, load shedding schemes, peak shifting opportunities and substation sizes.

One widely used model for system expansion is the Wien Automatic System Planning Package (WASP) developed by the Centre for Environmental, Energy and Economic System Analysis, Argonne Laboratories**.** WASP uses total system costs, fixed and variable operation and maintenance costs as well as fuel costs to determine the least cost expansion plan.

The use of mathematical programming for energy planning is not strictly the domain of the utility practitioner. Governments have often used mathematical methods in energy policy; in such cases they tend to employ econometric techniques which seek to relate the changes in the general economy to the electricity sector.

Notwithstanding the merits of optimization techniques, it is clear that the use of these methods alone does not allow decision makers to adequately address all the wider socio environmental impacts and different stakeholder perspectives. To adequately achieve this, one needs to use models with the capability of making comparisons and assessing the merits of each trade off. The field of multiciteria decision analysis (MCDA) offers a number of techniques which seek to meet these challenges. A variety of these have been applied to issues of sustainable energy.

In this paper we assess the techniques which have been most widely used in similar multicriteria problems and explore its potential use in energy regulation.

MULTI CRITERIA DECISION ANALYSIS (MCDA)

Multi Criteria Decision Analysis methods are rather different from the mathematical optimization techniques discussed earlier. Mathematical optimization techniques deal primarily with continuous variables such as, number of kilowatt hours or costs per installed KW; whereas MCDA focuses on decision making where there are a set of discrete alternatives to be considered. MCDA has been used in attempting to answer the following questions relating to energy, each of them has relevance for energy regulation.

1. What source of energy should be used?
2. What pricing should be adopted?
3. Where should plant be located?
4. What is the appropriate energy policy?

In analyzing multi criteria problems of this type, five aspects must be always taken into account. This combination of factors is commonly referred to as the CAUSE checklist.

1. C- Criteria
2. A- Alternatives
3. U- Uncertainties
4. S- Stakeholders
5. E- Environment

Criteria and alternatives can be considered the core aspects of CAUSE and critical in defining the problem. Understanding the uncertainties, stakeholders and the environment helps in improving the methods of how criteria and alternatives are determined and assessed. We now explore each component of CAUSE briefly.

Criteria

It is essential to determine the criteria that must be taken into account in making any decision. This is the rationale on which the decision will eventually be based. Having identified the criteria, the decision maker goes through a process to determine the relative importance of each criterion. The relative importance of each criterion is expressed through the assignment of weights; the scales use for weighting can vary. In one application a weighting of 5 may be considered for a very important criterion and a waiting of 1 for a trivial component. In other cases where there are more aspects being considered weightings may range from 1 to 100 or more. There are some situations where weights are not used directly and criteria are simply ranked ordinally. Determining the criteria weights is not a straightforward task and these values must be based on well researched information involving various stakeholders.

<u>Alternatives</u>

Once the criteria have been defined the decision maker assesses to what extent each alternative fulfils the criteria. This is determined by how well each option fulfils the requirement of each individual criterion. Each alternative is assigned a rating on each of the criteria. Each option is allocated a final score, which is defined as its utility, given by the cumulative score on each criterion. As is the case for criteria weights ratings can be based on a scale 1-5,1-100 or even 1 to 1000. It is not uncommon for qualitative scales to be used including terms such as (Weak, moderate, good, excellent) which may then be converted to numerical scales. There is software available capable of making such conversions, one popular programme is MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) developed in the early 1990s.

In the example below, a decision is to be made between the alternatives, of adopting a diesel, natural gas or wind generator for energy production. The criteria to be considered are installation cost, fuel cost, environmental impacts and training needs. The weightings of each criterion were assigned as follows.

1. Installation 3
2. Fuel Cost 4
3. Environmental impact 2
4. Training needs 1

Scores on each Criterion

	Installation	Fuel Cost	Environment	Training
Natural Gas	3	3	3	2
Diesel	2	1	1	4
Wind	1	5	5	1

Utility on each criterion = (score on criterion x weighting)

Total Utility = Sum of utilities of all criteria

Weighted Scores

	Installation	Fuel Cost	Environment	Training	Total
Natural Gas	3x3 =9	3x4=12	3x2=6	2x1=2	29
Diesel	2x3=6	1x4=4	1x2=2	4x1=4	16
Wind	1x3=3	5x4=20	5x2=10	1x1=1	34

In this example wind generation is the favoured option having obtained a utility of 34.

Uncertainties

In any analysis where there are a number of variables being considered, it is important that the uncertainty in each value is taken into account. The uncertainty is further exacerbated in MCDA when the values are based to some extent on personal judgement. The weightings of the criteria depend on the perspective of the decision maker, who will always have an inherent bias. The utility functions of the alternatives being considered are also subjective.

It may seem that with such levels of uncertainty, the results of such a process are unreliable. However if the appropriate technique for managing these uncertainties is applied, the results obtained can be very valuable.

The most widely used methods for assessing uncertainties are sensitivity analysis and stochastic techniques.

Sensitivity Analysis

Sensitivity Analysis considers the effect of a change in each of the variables involved on the decision taken. The decision maker may modify a single variable at a time by a percentage (usually up to about 10%). This allows the decision maker to recognize which of the factors involved are likely to lead to an erroneous result if there is an error in the input value.

Stochastic Techniques

Stochastic methods take into consideration that each piece of data entered is subject to an uncertainty, equivalent to a randomly generated probability distribution function around the value itself. In stochastic methods probability function is input rather than a single value. (Ladehlma et.al, 2002). Stochastic methods are often used if only ordinal (i.e 1^{st}, 2^{nd}, 3^{rd}) information related to the criteria is available, or information related to weights is not reliable.

Stakeholders

The fact that there is ultimately one decision maker or team of decision makers that makes a determination, often means that the diverse views that were brought to the table, before the decision was made are not adequately represented. Indeed, quite often stakeholders are overlooked entirely during the decision making process and this can lead to lack of acceptance when the decision is made public. Regulators attempt to deal with the involvement of stakeholders through written and oral consultations. In MCDA stakeholders should be involved in determining the criteria, assigning weightings and establishing the list of alternatives. In publishing decisions the regulator can represent the diverse views even as the course of action that was decided upon is explained.

Environment

In this context, the term environment goes beyond the narrow definition of the natural or biological surroundings. It refers to all the social political and economic factors which may have an effect on a decision. This factor relates to uncertainty but is very much more related to changes pertaining to external or exogenous factors. These exogenous factors in the case of energy may include trends in the economy relating to liberalization, competition policy, world oil prices or environmental regulations.

These factors can be taken into account through scenario analysis or the inclusion of "risk" among the criteria for MCDA.

Scenarios

Models may be used which analyse the options within different future environments referred to as scenarios. Common scenarios could include; Business as usual (i.e. the assumption that current practices and trends continue); sustainable development (assumption that policies undertaken will factor in long tern environmental and social consequences); resource constraint (assumption that access to energy products becomes limited). Developing models which addressed the "what ifs", are able to help the decision maker by giving an idea of what factors could lead to a change in adopting a particular course of action. Scenario building is in this sense a logical extension of sensitivity analysis.

Risk Factor

Uncertainties in future scenarios can be included at the level of determining criteria by allocating a risk factor. If an option's viability could be severely affected by a change in the wider environment, it will have a higher associated risk and this can be weighed against other criteria such as costs and quality.

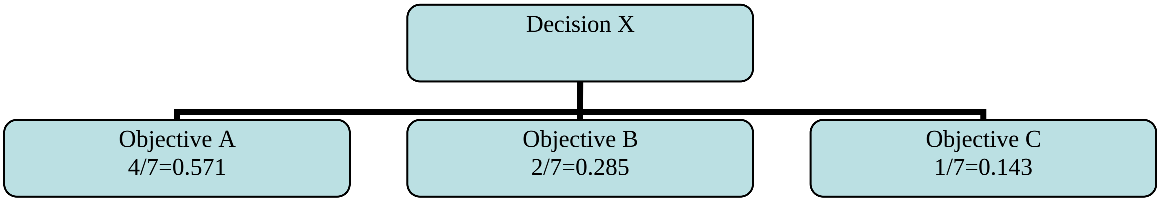
MCDA METHODS

An in depth analysis of methods used in MCDA reveals that there are two general methods which can be used separately or in combination.
1. Analytical Hierarchy Process 2. Outranking Methods.

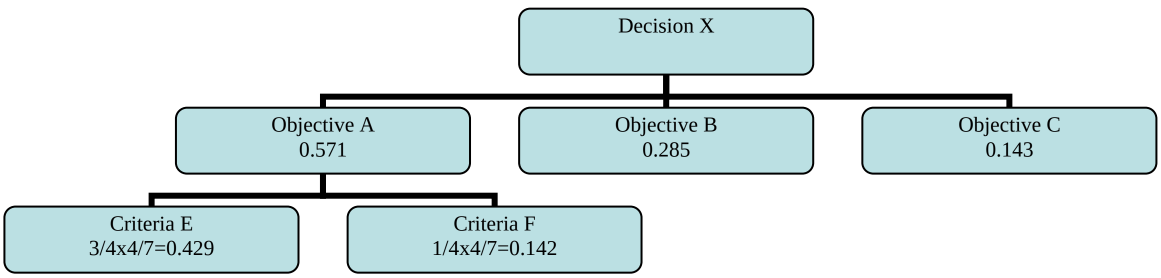
Analytical Hierarchy Process (AHP)

This is a monocriterion synthesis approach, which was developed by Michael Saaty in the 1960s. This method makes it easier to determine criteria as the problem is disaggregated into a hierarchy of interrelated decision attributes. The most macro-decision objective lies at the top of the hierarchy, while the lower levels of the hierarchy contain more detailed descriptions or groups of criteria that contribute to the quality of the choice between alternatives. Weights are estimated through a pair-wise comparison of decision elements. The weights developed at each level of the hierarchy are aggregated into an overall ranking for an alternative.

An example of the process is presented below. A decision X may have 3 over arching objectives A, B and C. A compared with B may be determined to be twice as critical and B compared with C as twice as critical as C. The weights of the objectives are normalized (i.e. A, B and C are set so that all weights sum to one). Accordingly, A is assigned weight 0.571; B is assigned weight of 0.285 and C a weight of 0.143



Objective A may be dependant on two criteria E and F where E is considered to be 3 times as important as F. The weightings of criteria E and F must sum to the weighting of objective A. This method is extended until criteria and sub criteria of all of the objectives are obtained.



Examples of application of this method to energy issues include the development of national policy (Hamalainen, 1990;), electricity generation expansion planning (Mills et al.,1996; Akash et al., 1999).

<u>Limitations of AHP</u>

Although this procedure simplifies the process of assigning weights to criteria, it has its limitations. Pairwise comparisons may not produce consistent results. If x = 3y and x= 5z, implies mathematically that y= 5/3 z. However a direct comparison between x and z may indicate that y= 2z. This is an example of an inconsistent result which leads to difficulties in further comparisons, however an inconsistency of less than 10% is considered acceptable in many applications.

Another drawback of this system is that it does not cater for the effect of lower level element on a higher level objective. It neglects the effect of feedback in the system. In reality there tends to be a network of criteria and objectives rather than a strict hierarchy.

Outranking Methods

Outranking methods also include pairwise comparisons but in this case thresholds are developed to define strong or weak preferences between alternatives determine when alternatives are close enough together to be considered equivalent or at least cause hesitation on the part of the decision maker. There have been many computer programmes developed which compare options through outranking techniques. Some are designed to allow graphical representation of results in a manner which can easily be interpreted by a decision maker (Decision Lab 2000, www.visualdecision.com). Many are robust enough to provide good results even when there are deficiencies in information.

Two popular methods which are used are the Electre and Promethee methods.

The Electre Model.

This outranking model was developed by B. Roy and D. Vanderpooten in 1965. Electre is an acronym for “Elimination and Choice Expressing the Reality.”

Electre III is considered to be the best method to be used in multicriteria decision making when the following circumstances are present.

1. At least 3 criteria
2. Intervals on criteria scales are not consistent
3. Strong heterogeneity among criteria
4. Compensation on one criteria by another may not be acceptable
5. Small preferences may not be significant but aggregates of small preferences may be.

Promethee Method

This method was developed by J.P Brans in 1982. Promethee is an acronym for Preference Ranking Organization Method for Enrichment Evaluations.

In Promethee models the software to quantitatively determine the extent of how much one option outranks another, taking into consideration that there are positive and negative flows when rankings are represented. This means that when an option “A” is compared with an option “B,” A will outrank B in some aspects and B will out rank A in other aspects. The net effect of these will determine whether A is outranking or being outranked. Computer models compare simultaneous the out ranking power of each option relative to all other options to determine net ranking. If an option “A” is superior to another option “B” in all criteria “A” is said to exhibit strict preference over “B”, this means that the weighting of criteria will not affect preference. Promethee methods are ideal for use in situations where the weightings of the criteria are uncertain. Some Promethee programmes allow the decision maker a range of allowable weights for different criteria, ascertained from stakeholders. This approach can allow decision makers to eliminate certain options from the outset even if there is a large level of uncertainty in weightings.

MCDA IN ENERGY APPLICATIONS

The use of MCDA in energy began in the late 1970s and was driven by the international trend which saw previous state owned monopolies becoming private entities. When power companies were essentially state owned monopolies, decisions were taken with broad social political issues in mind. The movement towards privatized companies meant that regulation was needed to ensure that while economic efficiencies were achieved the overall social welfare and consumer protection was maintained. MCDA methods were useful in attempts to balance these objectives. The establishment of sustainable development objectives, at the Rio Earth Summit in 1992, have given even more impetus in recent times to using MCDA to resolve conflicts between development of energy resources and protection of the natural environment.

MCDA over the years has been applied to a number of energy problems. Three of these are presented below and provide some insight into how MCDA techniques can be applied to energy policy and regulation.

Karni, Fiesin , Briener, 1992 " Multicriterion issues in energy policy making"

This study advocates the use of MCDA emphasizing the trade off between desirability of an energy policy and implementability. In the process, detailed sessions with stakeholders were used to identify criteria and weightings. The study recognizes the complexity of policy, appreciating that a policy alternative actually consists of a coordinated set of actions. In this case actions are defined and alternatives based on a combinations of actions. Actions include activities related to energy pricing and legislation. Overall policy is then defined as a set of consistent actions. Alternative policies were defined as balancing the accounts (financial), short term economic, and long term economic, conservationist and current policy.

Jones, Hope, Hughes, 1990, " A Multi attribute Value Model for the Study of UK Energy Policy"

In this study 25 persons from 16 organisations were identified as stakeholders whose views should be considered. These included energy industries, political parties, pressure groups and trade unions. Thirty criteria were identified and stakeholders were asked to pick the most important 15. For each of the 15 that were chosen the stakeholder had to identify the appropriate indicator measurement for the attribute. Having picked the indicator, stakeholders were then required to pick the "best case" and "worse case" values for each criterion. Criteria were divided into (economy, environmental, political, social, and technical). Attribute ratings were rated on scale 1-100.

5 options were assessed representing possible scenarios varying in energy generation mix. For each option a score on each attribute 1-10 was given.

Georgopoulou, Lalas, Papagiannais, 1996-, " A Multicriteria Decision Aid approach for energy planning problems: The case of renewable energy option

This paper uses MCDA for dealing with Renewable Energy policy criteria applied to a project on the Greek island of Crete. Alternative strategies identified included Utility Oriented, Energy Demand Oriented, Moderate and Centralised renewable energy system (RES) development, Moderate and Balanced RES development, Collaborative, Maximalistic and Innovative.

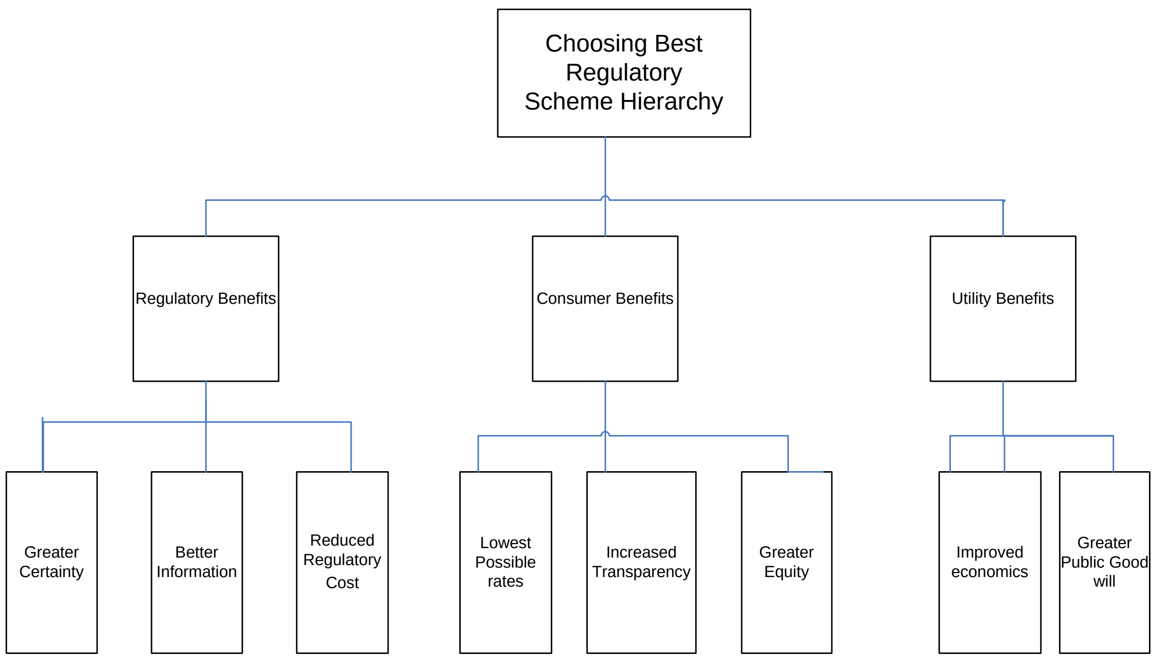
Criteria chosen include both quantitative and qualitative aspects.

- Investment cost
- Operation Maintenance Cost
- Safety in covering peak demand
- Operationality
- Stability of Network
- Cohesion to local economic activities
- Regional Employment
- Air Quality
- Noise
- Visual Amenity
- Depletion of Finite Energy Sources
- Risk of climate change
- Eco system's protection
- Land Use
- Implementation EU

USE OF MCDA TO ESTABLISH REGULATORY POLICY

Following on from the methods discussed earlier applying MCDA to energy policy, in this section we develop a framework assessing regulatory policy related to energy. The model is not presented with a view to evaluating the options, but demonstrates how a framework could be developed based on the MCDA principles. The example uses the AHP method. It should be noted that one of the outranking methods could be used to determine the best decision based on weights obtained from AHP.

The first step is the development of a hierarchy of objectives and criteria.



In the scheme above the objectives are divided so as to treat individual stakeholder interest under separate objectives. Weightings would be determined by a method similar to that which is explained in the section which explains AHP methods. The eight criteria could then be further broken down into sub criteria.

For example, improved economics for the utility could be depend on improved maintenance practices, increased efficiencies and better environment to attract investors.

Greater equity could be affected by reduced cross subsidies in rate structure and a method of ratemaking where rates are more closely linked to costs incurred.

In the next step we determine actions which could be considered part of a regulatory policy and amalgamate complimentary actions into comprehensive policies in a manner similar to that employed by Karni et. al (1992.). Regulatory policy will include decisions relating to method of regulation, accounting methods, rate setting principles, methods of reporting, standards and targets.

Giving due consideration to each factor 12 “action” decisions are stated as important in establishing policy. Each action consists of a number of discrete options, which will need to be specifically defined. Qualitative definitions such as low medium and high will need to be transferred to quantitative scales to allow for direct comparisons.

- Regulatory Method (Rate of Return, Price Cap, Hybrid, None).
- Accounting Method (Historical Cost, Fair Value)
- Rate Setting Method: (Embedded Cost, Marginal Cost, Subsidised)
- Frequency of Regulatory Reporting : (Monthly, Quarterly, Yearly, None)
- Detail of Regulatory Reporting. (Low, Medium, High)
- Frequency of Regulatory Review: (Monthly, Quarterly, Yearly)
- Frequency of Rate Review. (Yearly, 2 years, 3 years, 5 years, 10 years, undetermined with limit, undetermined without limit)
- Target Setting (None, Voluntary, Mandatory/ Voluntary, Mandatory)

- Public Consultation Frequency. (Monthly, Quarterly, Biennially, Yearly, as needed with minimum defined, as needed with minimum undefined)

- Public Awareness Detail (None, Low, Moderate, High, Very High)

- Level of Legal Sanctions (None, Low, Moderate, High, Very High)

- Level of Involvement in Utility Planning (None, Low, Moderate, High, Very High)

Each alternative action will tend to favour different criteria. A rate of return mechanism will favour the criteria of certainty for the utility in earnings meanwhile a price cap mechanism would favour the criterion related to improving efficiencies. The relative weightings of the conflicting criteria would determine which regulatory method is most appropriate. There is however further complication in determining which actions are compatible in developing policy. The analysis may determine that incentive is the best method of regulation but may determine that socially driven government subsised rate making is also preferred. These two actions may be most desirable when considered individually but may be counter productive if embarked on simultaneously. To deal with such issues the actions may be consolidated as shown below ranging from high government controlled regulation to open market.

<u>Alternative Policies</u>

1. Government Command and control.
2. Highly Regulated (Public Information Oriented)
3. Social (Focus on needs of low income)
4. Regulated (Cost Oriented)
5. Incentive Efficiency Orientation
6. Deregulation, Open market- Competition oriented

The decision makers will then be required to determine which action decisions 1 -12 could make up the six alternative policies. Although there are some decision actions that could be part of many policies there are some actions which would not be complimentary to some policies. For example, an action of a yearly rate review would not be compatible with a strategy geared towards an open market environment. Determination of which actions are compatible with which policies is an involved process, which would need to involve utility representatives, regulators and government officials.

It is often difficult for all stakeholders to understand individually the effect of a seemingly unrelated action to other elements of policy. The final step would be to determine the score of each consolidated policy based on the weightings obtained from the AHP.

Conclusion

The analysis of the decision methods above reveals that there is significant potential for the use of multi criteria decision analysis in the regulation of energy and energy planning in general. Understanding how criteria fit into overall objectives will to some extent reduce the ad-hoc decision making processes which are now in place that often lead to contradictions and lack of coordination in options taken.

However, the limitations in the methods must also be taking into account, recognising that depending on the level of detail this can be significant or negligible. Limitations in no way take away from the usefulness of these models which must always be seen as decision aids rather than decision makers. Decisions at the end of the day are made by people and not machines and even though the programme may reflect the human empirical inputs, it is impossible to capture every nuance that may swing a decision.

The hope is that with these methods transparency in decision making can be increased and when decision makers feel the need to sway from the numbers, they will be forced to provide an acceptable explanation .

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