

Decube Framework: An Introduction to a New Energy Modelling and Planning Process for Sustainable Utilisation of Pakistan’s Energy Resources

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1. INTRODUCTION

Sustainable Development—which ensures that the use of resources and the environment today does not restrict their use by future generations [UNEP (2007)]—is the most significant challenge facing today’s governments. Consequently, the notion of Sustainable Development [Matthews (1979)] has become a fundamental part of any policy and decision carried out at national and international levels. If the current acceleration of human advancement is not reduced it poses the biggest threat to long term sustainability of the entire globe, arising from the development and industrialisation in the twenty-first century, dwarfing the impact of twentieth century. This further compounds the work of policy-makers faced with the challenge of fast tracking the economies of developing countries.

Since the Industrial Revolution energy has become the lifeline of economic development and progress. This led to exponential increase in use of fossil fuels. However, rampant, unchecked and accelerated burning of fossil fuels in the twentieth century has resulted disastrous and long term damaging effects to earth’s climate. Consequently, world has begun this century with the aim “to develop a coherent and practical approach to climate change [World Energy Council (2007)].” “Safe, environmentally sound and economically viable energy pathway that will sustain human progress into the distant future is clearly imperative [WCEW (1987)]” to achieve the above goal. As a result environment has become an integral part of any energy system and policy. On the whole today’s energy policies and decisions have to be carefully woven into an intricate web traversing the boundaries of economy, environment and society.

Since the oil embargo of 1973 and its lifting with astronomical rise in the oil prices, energy policies have become a vital part of long term planning throughout the globe. Governments and research organisations have developed numerous tools and techniques to help better predict energy demands and supplies. One of these tools is energy modelling. Energy modelling is used for the purpose of energy scenario development and forecasting future energy demands.

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In this paper we propose a new energy modelling process, namely: Decube Framework, designed specifically for a developing country like that of Pakistan. Decube Framework aims to help the policy and decision makers by forecasting future energy demands and then assisting them in drafting a plan for energy supplies. It then takes them towards developing a policy and finally an action plan.

This paper is divided as follows. First it provides an introduction to energy modelling in section two followed by a quick discussion on the need for a new energy modelling framework in section three. Section four provides an overview of Decube Framework. Section five discusses the potential of Decube Framework in Pakistan's energy policy structure and the paper ends with some concluding remarks in Section six.

2. ENERGY MODELLING

Modelling energy system of any country these days presents the decision and policy makers with a daunting and formidable task. It entails an array of technical, social, environmental and economic aspects of a country. In order to help the policy-makers researchers have developed different modelling schemes and paradigms usually termed as modelling approaches. These models define the energy system of a country in terms of its typology, interrelation of its various elements and relation with other elements of the economy, society and environment. Some go even further and cross the limits of national boundaries – modelling regional and global energy systems. Models based on different approaches tend to define and represent the energy system in different ways and as a result highlight different features and are interpreted differently. Top-down and bottom-up are the two modelling approaches to represent interactions between the energy system and the economy [Bruse, *et al.* (1996)]. Numerous energy modelling systems have been developed on the basis of these two approaches. The bottom-up models are technology focused and top-down models focus on macro-economic interactions. In the following Table (1) main characteristics of the two approaches are compared.

Table 1

Main Characteristics of the Two Approaches

Economic (Top-down) Models	Technology (Bottom-up) Models
Equilibrium feedbacks are inherent in these models and are Generally Macro-econometric (GME) or Computable General Equilibrium (CGM)	Equilibrium feedbacks are partial or missing
Technological change is depicted abstractly through input substitution and autonomous energy efficiency development parameters	Technologies are depicted explicitly and chosen via financial cost minimisation, usually with perfect foresight
These models neglect details about technology and energy	Well suited for analysis of changes in technology and/or energy efficiency standards
Energy modelling is based on the description of macro-economic relations in the region under consideration	Not suitable for economy-wide interactions, incorporating income effects, and price distortions

2.1. Economic (Top-down) Models

Economic models tackle energy modelling by describing macro-economic relations in the region under consideration. This allows these models to capture a large set of economic interactions including inter-industrial relations and macro-economic feedbacks without representing explicitly energy technology options. For policy formulations these models incorporate feedback effects between different markets triggered by policy-induced changes in relative prices and incomes.

On the down side, these models usually neglect details about technology and energy. This is due to the inefficiency of these models to follow physical laws such as conservation of matter and energy and inaptness to incorporate different assumptions about the changes in energy technologies and costs. This inability of top-down models is usually traced to their trait of representing energy sector in an aggregate way by means of smooth production functions which capture substitution (transformation) possibilities via substitution elasticities. Consequently, economic adjustments are also sometimes overemphasised.

Majority of the currently available energy models are based on top-down approach. MDM-E3 [Cam (2007)] model originally developed in the Department of Applied Economics, University of Cambridge is a typical example of this approach.

(i) *Multi-sectoral Dynamic Energy-Environment-Economy Model (MDM-E3)*

The MDM-E3 (Multi-sectoral Dynamic Energy-Environment-Economy Model) [Cam (2007)] developed by the University of Cambridge and Cambridge Econometrics is designed to analyse and forecast changes in economic structure, energy systems and associated environmental impacts for use in policy making. The model works by disaggregating industries, products and household, and government expenditures, as well as foreign trade, and investment. [Cam (2007)] It is a complex model with a combination of time-series econometric relationships and cross-sectional input-output relationships. Another strength of the MDM-E3 model lies in aggregation of demand in a neo-Keynesian manner with a consumption function and investment equations. Average earnings by industry and region, export and import, and regional employment can also be equated in the model [Cam (2007)].

2.2. Technology (Bottom-up) Models

The technology (bottom-up) models propose a technology rich description of energy systems describing current and prospective technologies in detail. These models compute partial economic equilibria in the energy sector usually under different constraints such as those of Greenhouse Gases (GHGs). These models are usually designed as mathematical programming tools. Comparing with the economic models, these models assume perfect foresight and produce optimised technology investment policies usually spanning over a period of decades, e.g. 4 to 5 decades in MARKAL.

(i) *Market Allocation Model (MARKAL)*

Market Allocation Model (MARKAL) [Mar (2007)] is a generic model tailored by input data to represent evolution over a period of usually 40 to 50 years of a specific

energy system at national, regional, provincial or communal level. Currently 77 institutions in 37 countries use MARKAL family of models. This model like other bottom-up models assumes perfect foresight and produces optimised technology investment policies over a planning horizon of 4 to 5 decades [Mar (2007)].

2.3. Hybrid Models

Beginning of this century researchers and policy-makers started to realise the inherent limitations of the two modelling schemes and started working towards combining the strengths of the two into a newer modelling framework, although the earliest research in this converging work goes back to mid seventies [Hudson and Jorgenson (1974)]. Thus far the research has resulted into models like Energy-Economy-Engineering-Environment (E4) Model [Terry (2005)] Reduced GEMINI-E3S Model [Loulou (2005)], CIMS [CIM (2007)] and others [see Boehringer (1998); Frei, *et al.* (2003); Kumbaroglu and Madlener (2003); and McFarland, *et al.* (2004)].

(i) *Canadian Integrated Modelling System (CIMS)*

CIMS (Canadian Integrated Modelling System) [CIM (2007)] is a hybrid energy-economy model and has the ability to model equilibrium feedbacks while being technologically explicit and behaviourally realistic [Murphy, *et al.* (2007)], and is ideal for modelling air quality and GHG emissions [CIM (2007)]. It has been developed by the Energy and Materials Research Group and M.K. Jaccard and Associates (EMRG/MKJ) at the School of Resource and Environmental Management at Simon Fraser University.

Having a hybrid nature CIMS integrates the set of economic and energy modelling, and provides a wide range of combined energy and economic analysis. Energy flows are tracked beginning with production processes through to eventual end-use by individual technologies. Being a full equilibrium model CIMS incorporates macroeconomic demands feedbacks, second order macroeconomic effects, demand dependent energy supply costs and energy trade [CIM (2007)].

3. NEED FOR A NEW FRAMEWORK

Development and progress have been the principium of human civilisation since its birth. In its infancy energy in the form of human muscle like slavery and nutrition i.e. agricultural produce spanned the entire horizon of any energy system. Life and development depended upon these two and other accessories were traded for these. During Industrial Revolution machinery replaced human muscle and unlike slaves it fed on fossil fuels; a newer form of energy. Further development of civilisation now rested on the acquisition of this new energy resource. This was evident throughout the twentieth century, however, twenty-first century saw the issue of environment i.e. sustainability of resources for future generations becoming a new pillar in the equation.

Late last century, researchers and scientists started raising the issue of Climate Change and Global Warming caused by the uncontrolled burning of fossil fuels. This and the necessity of continuous energy supply led to birth of energy planning models. These models were developed with the aim to help plan future needs and supplies with regard to energy, environment and economy. Though useful for developed countries, these models

have not been very successful in developing countries in accurately forecasting energy demands, Pakistan being one example. Apparently, one factor is inherentness of these models to work with the aim of developing a scenario or calculating demands with some sort of constraint as the central variable of the equation such as emphasis upon conservation and reduction of energy wastage. While this works for the developed world, in the developing countries the central variable in any economic planning is opposite to that of any sort of constraint. Main aim of policies in these countries is to foster growth, progress and development at any possible and feasible rate. With economic policies being developed with such goals and energy policies developed to work under a multitude of constraints, no wonder these countries fail to project accurate energy demands.

The need now is to develop an energy modelling process specifically catered for a developing country with a niche to foster development and growth in the economy. Also, if the process has the capability to guide the policy makers to first develop an energy scenario and then forecast an energy demand and continuing on to help them write-up energy policies and create an energy action plan it would further optimise the final product. This paper is an attempt in this context, proposing, “Decube Framework”—a process that incorporating all the above components and designed specifically for a developing country like that of Pakistan.

4. THE DECUBE FRAMEWORK

Decube Framework—the name based on development, environment, economy and energy—designed specifically for a developing country presents a methodological sequence of steps from initial planning phase for forecasting future energy demands to the development and implementation of an action plan.

No matter what kind of energy policy is being developed whether environmental or renewable, development and progress cannot be overlooked. In fact, energy utilisation in itself spurs progress and development. This is why development has been included in the name of Decube Framework itself. The energy policy might be sustainable or not, might be environmentally friendly or not but it will always be pro-development and progress. These characteristics are intended to be infused in the current framework. Other than being pro-development the Decube Framework provides a systematic approach to:

- Guide the policy-makers from initial vision to the preparation and implementation of action plan;
- Create a realistic scenario and accurate energy demand for short to long term planning;
- Create clear pathways leading to the development of the scenario;
- Scenario harmonisation at national level and if required at regional and global levels; and
- Allow possible combinations of options (technological, institutional and behavioural).

The Decube Framework has been designed in a set of four phases (Figure 1), each phase building upon the work carried out in the previous phase (Table 2). The four phases are discussed in the following lines.

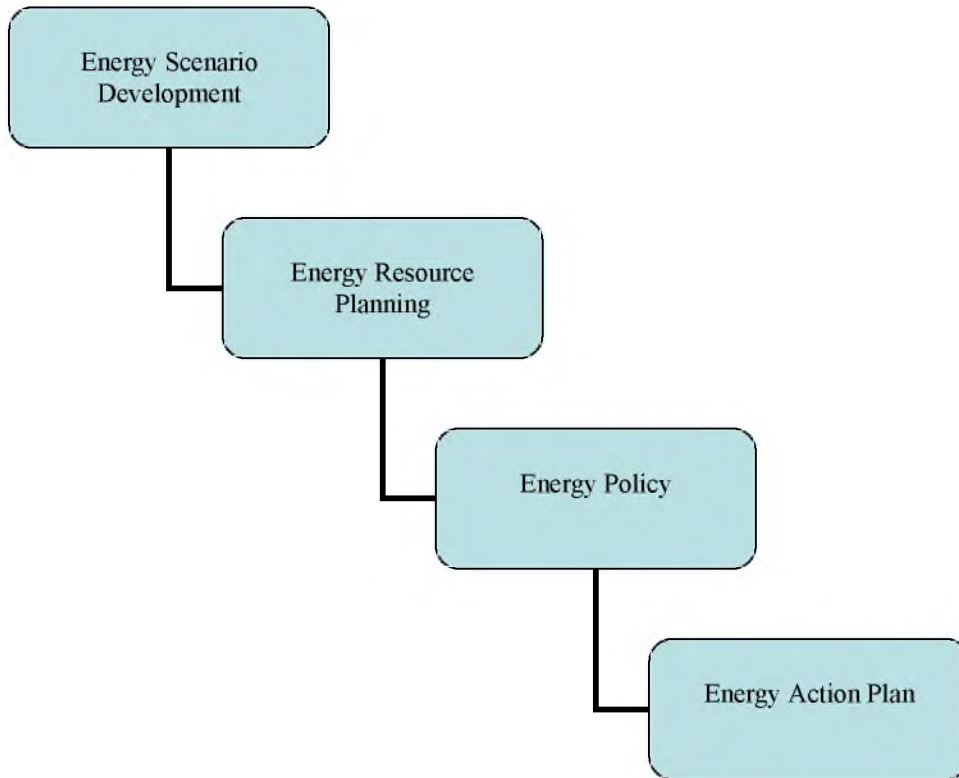
Fig. 1. The Decube Framework Phases

Table 2

Deliverables of Each Phase

Phase	Question Answered	Deliverable
Scenario Development	What is the aim? Or what will be the energy demand?	Energy Scenario and Energy Demand
Energy Resource Planning	What resources are needed to achieve the aim?	Identification of potential energy sources
Energy Policy	What is required to ascertain the identified resources?	Complete Energy Policy
Energy Action Plan	What actions are needed to achieve the goals identified in Energy Policy?	Complete Energy Action Plan

4.1. Energy Scenario Development

Energy “Scenarios are alternative images of how the future might unfold and are an appropriate tool with which to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties” [Nakicenovic and Swart (2000)]. For an accurate forecasting of energy demands, building up a precise energy scenario is an integral component. Majority of inaccurate energy

demand forecasting can be traced back to flawed scenario development. For a developing country like Pakistan, the scenario development has to account for the inherent potential of the economy for growth and progress. This means inclusion of the “uncertainty” factor which might be unprecedented growth or a slowdown interval in the economy. Energy scenario development is also a systematic process starting from the collection of data on key drivers. There are some key drivers like that of energy infrastructure, energy intensity of industrialisation, consumption pattern and travelling habits which help optimise an energy scenario. It is paramount that all the possible drivers are included during this process. For the purpose of collection of data, a well suited research method needs to be followed. The collected data is then plotted in either forecasting or backdating [Robinson (1990)] method which produces the energy scenario. All of these steps are discussed below:

(i) Key Scenario Drivers

Key areas which a scenario needs to incorporate for higher accuracy span over a multitude of sectors including demographic transitions, human capital, productivity, growth and sustainability. A typical scenario should include among others the following variables for accurate predictions:

- Energy
 - Energy Resources, Infrastructure, Technologies, Efficiency and Conservation
- Productivity
 - Labour Supply, Quality of Human Resources, Land-Use, Capital (Savings/ Investments)
- Business Demand/Behaviour
 - Travel Patterns
- Transportation Sector
- Industry
- Consumer Behaviour/Preferences
 - Travelling Habits, Product Preferences
- Agriculture
- Government Expenditure
- Urban Planning and Construction
 - Architecture/Building Codes, Land use policies, Public Transport, Building Materials, Design
 - Reduce, Recycle and Reuse (3R)
- Planning and Governance
 - Laws, Policies, Rents, Taxes
- Demographics
 - Population Growth, Age Profile
- Economy
 - Economic Growth, Sources of Growth
- Global/External
 - International Trade, Geopolitical Risks

(ii) Research Method

To build an accurate energy scenario, a vigorous research methodology is required for data collection. Any typical research methodology should encompass:

- Macroeconomic forecasting of the economy;
- Historical analysis of activity drivers; and
- Interviews with industry leaders (key informants survey) for future industrial situation.

(iii) Scenario Development Methods

As shown in the Figure (2) below, scenario development is achieved through either building back from stories and predictions or moving forward based on a modelling scheme in a qualitative manner. The latter usually incorporates a simulation modelling software and it is the strength of this software which produces the capability of the scenario to accurately describe a futuristic picture. A quick comparison of the two approaches is provided in the following Table (3).

Fig. 2. Energy Scenario Development Methods [Nakicenovic and Swart (2000)]

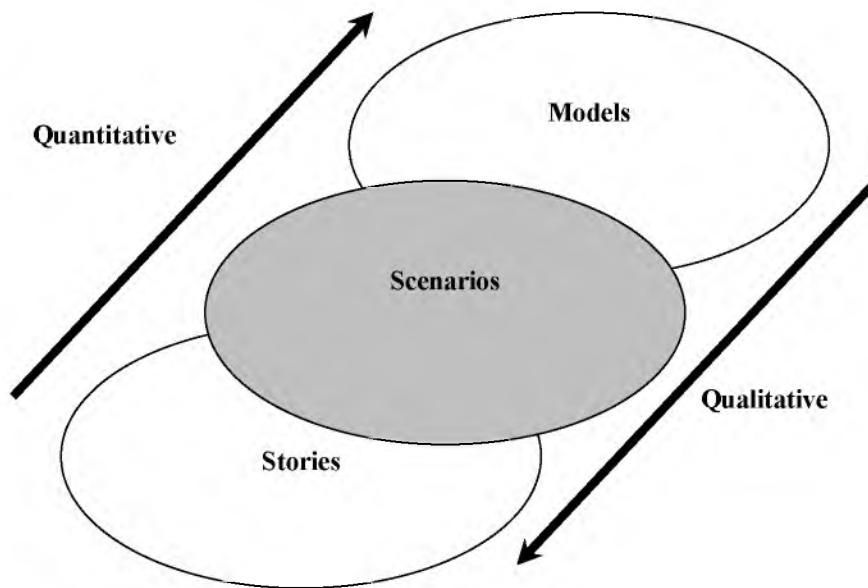


Table 3

Difference between Stories and Modelling Options

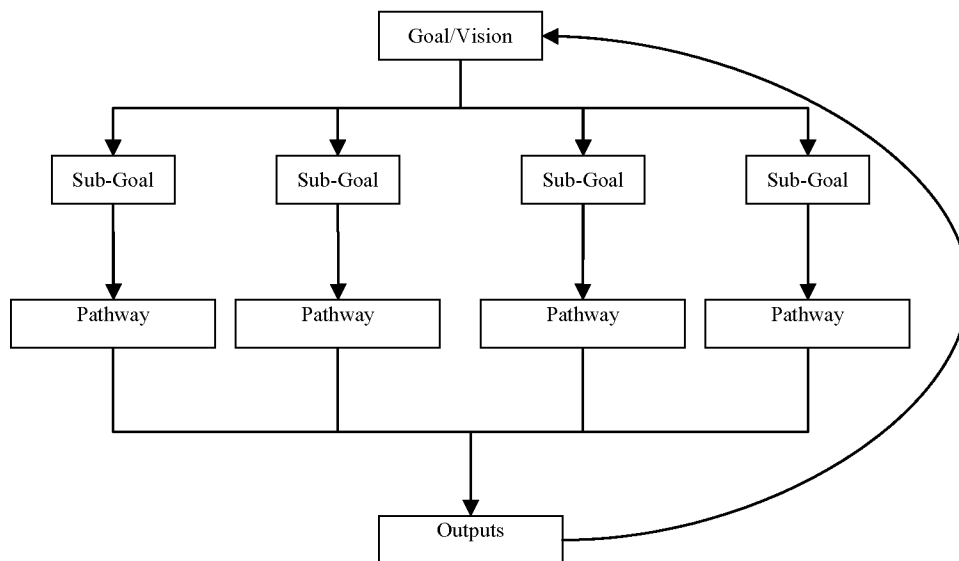
Stories (Backcasting)	Modelling (Forecasting)
Backcasting	Forecasting
Normative	Descriptive
Technical Vision/pathways	Optimisation
Future picture is envisioned and steps are then defined to attain those conditions	Steps are taken that are merely a continuum of present methods extrapolated into the future

Stories (Backcasting)

Backcasting stands out as an alternative to traditional forecasting technique [Robinson (1990)] as utilised in energy modelling processes. In this technique the future picture is envisioned and steps are then defined to attain those conditions (Figure 3). Following are the conditions which favour backcasting [Dreborg (1996)]:

- The problem to be studied is of a complex nature;
- Dominant trends are part of the problem;
- A major change is intended;
- The problem to a great extent is a matter of externalities; and
- The scope is wide enough and the time horizon long enough to leave considerable room for deliberate choice.

Fig. 3. Roadmap for an Energy Scenario through Stories



Modelling (Forecasting)

An Energy model is a mathematical tool or software based on this tool used for the purpose of forecasting or scenario analysis. Effective energy models (sometimes also referred to as analysis/assessment tools) are flexible and integrated enough to assess a range of scenarios and evaluate the impact of different scenarios. A typical energy model is concerned with answering the questions like:

- Where can the system go, if a specified technology is deployed?
- Where will the system go?
- Where should the system go?
- What policies have to be put in place to make the system track a particular trajectory?

4.2. Energy Resource Planning

Energy Resource Planning process usually focuses on two core areas:

- Energy source-related planning, such as electricity generation and bulk energy procurement; and
- Infrastructure-related planning, such as construction of new pipelines, power plants, or electric transmission and distribution projects.

The value of energy efficiency can be integrated into resource planning decisions for both of these areas. As identified by the World Bank, energy diversification of supplies is one of the three key pillars for global energy security; the other two being energy efficiency and dealing with volatility [Wor05], thus, any energy resource planning needs to rely on energy diversification for obtaining maximum energy security. The key areas which the planners need to look into include:

- Fossil/Renewable Energy Potential;
- Energy Import Prospects;
- Regional Energy Resources;
- International Energy Resources;
- Energy Resource Trading;
- Implications for Foreign Policy;
- National Requirements for Achieving above Targets;
- Human Resource Requirement;
- Industrial Resource Requirement; and
- Financial Resource Requirement.

4.3. Energy Policy

Based on the Energy Resource Plan obtained in the previous section, a comprehensive energy policy needs to be drawn. The policy needs to be an integrated energy policy. Developing different policies for different energy sources such as fossil fuels, renewable energies, energy imports not only leads to duplication of efforts at national level but also costs more resources. Additionally, the policy coordination and homogeneity becomes a major issue.

The ideal energy policy should be an integrated energy policy covering all aspects of energy. Once an integrated energy policy has been developed, only then can the policy-makers move on to the implementation phase.

4.4. Energy Action Plan

Development of energy action plan marks the start of the implementation phase. Based on the energy policy, an energy action plan is created which will outline the details for the implementation of the plans to achieve the identified targets. An action plan might include creation of new government bodies or might even introduce merger of existing departments for optimal outputs.

5. THE DECUBE FRAMEWORK FOR PAKISTAN

5.1. Pakistan's Energy Security Plan

Pakistan's primary commercial energy consumption stood at 55.5 MTOE (million tons of equivalent) in 2004-05 [Pakistan (2007)]. In addition to this, some 21 MTOE of traditional fuels (fuel wood, crop residues and animal wastes) were also used by the households and industry [Pakistan (2007)]. The current consumption of 55.5 MTOE of commercial energy will rise by 600 percent to 361.82 MTOE by 2030 (Figure 4, Table 4) [Pakistan (2007)], growing at a rate of 7.4 percent per annum till 2010 [Pakistan (2005)] and 8.8 percent after 2010 [Pakistan (2007)]. In electricity sector in 2004-05, the total electricity generation, although was more than the demand, but the line losses standing at 25.4 percent of net supply [Pakistan (2007)] reduced the total output, putting the demand higher than the supply.

Fig. 4. Energy Mix Plan Projections [Pakistan (2005)]

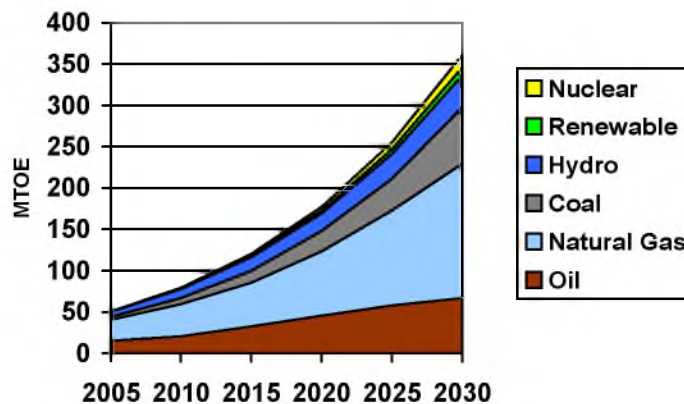


Table 4

<i>Energy Mix Plan Projections (MTOE) [MTD (2005)]</i>						
	2005	2010	2015	2020	2025	2030
Oil	16.54*	20.69	32.51	45.47	57.93	66.84
Natural Gas	27.92*	38.99	52.98	77.85	114.84	162.58
Coal	4.22*	7.16	14.45	24.77	38.28	68.65
Hydro	6.11*	11.03	16.4	21.44	30.5	38.93
Renewable	0	0.84	1.6	3	5.58	9.2
Nuclear	0.67*	0.69	2.23	4.81	8.24	15.11
Total	55.46*	79.4**	120.17**	177.34**	255.37	361.31

*Based on [Pakistan (2007)].

**Total different than in [Pakistan (2005), Table 3].

The above Figure (4) and Table (4) have outlined the desired share of different energy sources up till 2030. The experts have also projected the energy shares which the country would be able to meet in each category. According to these projections the country would be able to meet only 153.78 MTOE by 2030, less than half of the energy required at that time (Figure 5, Table 5).

Fig. 5. Indigenous Energy Supply Projections [Pakistan (2007)]

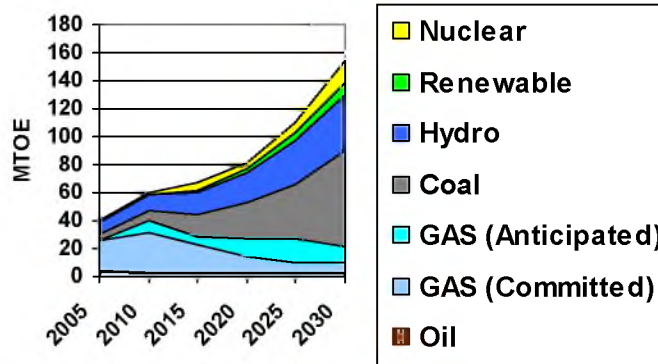


Table 5

Indigenous Energy Supply Projections (MTOE) [Akr (2005)]

	2005	2010	2015	2020	2025	2030
Oil	3.62	2.2	2.18	2.2	2.2	2.2
GAS (Committed)	22.3	29.93	20.22	11.81	7.29	7.29
GAS (Anticipated)	1.00	7.85	6.68	13.82	18.34	12.35
Coal	2.30	7.40	14.81	24.77	38.28	68.65
Hydro	9.24	11.03	16.4	21.44	30.5	38.93
Renewable	0	0.84	1.6	3	5.58	9.25
Nuclear	0.73	0.69	4.81	4.81	8.24	15.11
Total	39.19*	59.94	66.70	81.85	110.43	153.78

*Total different than in [Ark (2005)].

The current Energy Security Plan envisions that the country would start seeing a gap between the demand and supply beginning 2010 which would continue to rise (Figure 6, Table 6). In this forecasting model in which the country will only be meeting 37.5 percent of its total energy demands by 2030, the findings are that the country will not face any shortage until the year 2010. The ground reality is that the country fell short of 4500 MW of electrical energy alone in January 2008 [Bus (2007)].

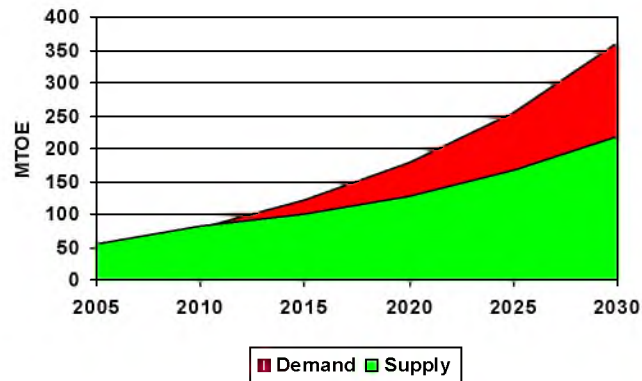
Fig. 6. Projected Gap between Supply and Demand [Pakistan (2005)]

Table 6

Projected Gap between Supply and Demand (MTOE) [Akr (2005)]

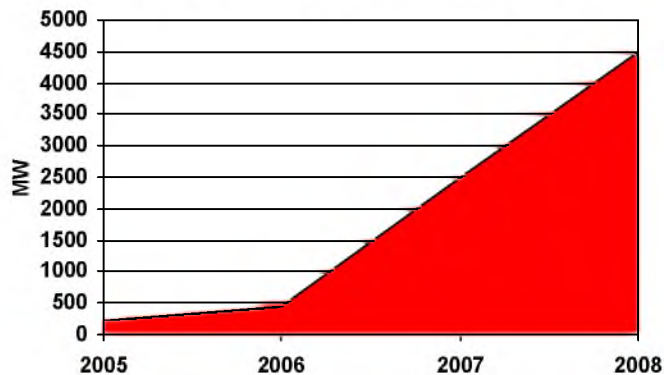
	2005	2010	2015	2020	2025	2030
Indigenous	39.19**	59.94	66.70	81.85	110.43	153.78**
Imported Oil	14.66	18.8	30.33	43.27	55.73	63.55
Imported Coal	1.00	2.0	2.0	2.0	2.0	2.0
Total Available	54.4	80.74	99.03	127.12	168.16	219.33
Total Demand	~55.5*	79.40*	120.17*	177.34*	255.37*	361.31*
Gap	0~1.1	-1.34**	21.14**	50.22**	87.21**	141.98**

*See Table 4, above.

**Total different than in [Ark (2005)].

5.2. Pakistan's Energy and Economy in 2008

Contrary to all the visions and forecasts Pakistan has started seeing an energy crises since the beginning of 2005. Increasing annually, the shortfall in the electricity sector alone has touched 4,500 MW on 6th January 2008 [Bus (2007)] (Figure 7).

Fig. 7. Electricity Shortfall since 2005

This shortfall is not only severely damaging the national economy but giving rise to instability as well. The current energy projections and models all have failed to predict any of the current situation and hence the need now is to quickly start work on re-forecasting and modelling of the energy system and then putting it into action.

5.3. The Decube Framework and Pakistan Energy Security

“For developing countries, the ‘good news’ is that their environment and natural resources policies are often so bad that there are reforms which would be both good for the economy and good for the environment [Stiglitz (2006)].” Pakistan has to take its cue from the current energy crises and start rebuilding its energy demand forecasting and policy development methodologies. The above Figure (7) shows the worsening shortfall in electricity production in the last three years. This shortage of electricity can be traced to the increase in the economic activity in the country as well as rising domestic consumers’ demand, which were not forecasted by current energy scenarios.

The Decube Framework can help Pakistani policy and decision makers in redesigning the energy forecasting model and then optimising the current energy plan based on the new forecasts. This intensive exercise needs to be taken as soon as possible to avoid any further damage to the economy and to help foster a prosperous Pakistan for future generations.

If Pakistan were to adapt Decube Framework or any other similar process, first step would be the data collection exercise. Any scenario projection can only be as good as the data input. Faulty data would surely give less than optimal scenario. Therefore a systematic and effective research plan needs to be executed for data collection exercise. The research plan should be tailor made for Pakistan to obtain maximum accuracy. Once the data is collected, it needs to be put in a scenario model for forecasting.

A new scenario model simulation software is needed to compute the data. The software needs to be purpose built for Pakistan. As already indicated the software needs to incorporate the ground realities dominant in Pakistan. This would further increase accuracy of the model. Usually the models span over a period of decades, which help the policy makers in long term plans. Therefore the simulation software ideally should provide a scenario model spanning over many decades.

Once a scenario model has been developed and energy required stipulated based on it, the demand would be projected. This would start the intricate of energy resource planning. This is a lengthy and sensitive process as the experts have to look at the geopolitical situations in the region and throughout the globe including many other factors such as country’s imports, national fuel sources and so forth. Once a detailed study on available and potential energy resources nationally, and international energy supplies has been carried out, a set of requirements would be drawn outlined in the form of infrastructure, imports, shift in policy, etc. This will then be used by the policy makers to draft a policy structure for energy in the country. Once an integrated energy policy has been drafted, the administration would then put it to implementation through an energy action plan, supporting and building upon the energy policy.

6. FUTURE WORK AND CONCLUSION

In this work an introduction to a new energy framework has been provided. Overall the current research is a preliminary work which needs to be carried further. The need now is to develop this concept into a comprehensive model which is then applied to Pakistan. This should be coupled with the development of a simulation software to optimise the energy scenario development and forecasting energy demands.

The first step ideally would be expansion of the framework into a complete model coupled with the development of a simulation software. For implementation in Pakistan, a quick feasibility study would be needed estimating the total cost and time required for the development of energy policy and energy action plan. Based on the feasibility study the execution of the project could proceed.

Energy is the lifeline in any economy and if Pakistan is to sustain its current acceleration of growth it needs a continuous and affordable supply of energy. This paper has been an attempt in this direction and has outlined a framework that is crucial to achieve the aim of energy sustainability.

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