SERI/RR-744-451

March 1980

MASTER

Decentralized Energy Studies: Compendium of International Studies and Research

Cissy Wallace

International Project for Soft Energy Paths
Friends of the Earth
San Francisco, California

SERI

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Operated for the
U.S. Department of Energy
under Contract No. EG-77-C-01-4042

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price:
Microfiche $3.00
Printed Copy $ 5.25

NOTICE

SERI/RR-744-451
UC CATEGORY: UC-58e

MASTER

DECENTRALIZED ENERGY STUDIES: COMPENDIUM OF INTERNATIONAL STUDIES AND RESEARCH

CISSY WALLACE

INTERNATIONAL PROJECT FOR SOFT ENERGY PATHS
FRIENDS OF THE EARTH
SAN FRANCISCO, CALIFORNIA

MARCH 1980

PREPARED UNDER TASK NO. 5629.99

Solar Energy Research Institute

1536 Cole Boulevard
Golden, Colorado 80401

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FOREWORD

This compendium was prepared as part of the Decentralized Energy Studies task at the Solar Energy Research Institute (SERI). The purpose of this document is to compile a brief description of some of the studies conducted in other industrialized nations on decentralized energy systems. This compilation includes studies involving energy systems that can in some way be described as small-scale, community-level, on-site, soft, appropriate, distributed, or renewable. This compendium is not meant to be comprehensive but to assist researchers and individuals in learning more about what other countries are doing to find alternatives to large, centralized energy systems.

"A Guide to Soft Energy Studies" by David Brooks and Sean Casey is reprinted in the Appendix. The article provides a particularly succinct description of the soft energy path analysis process and should be of interest to many.

SERI and the International Project for Soft Energy Paths would like to thank Alternatives and Friends of the Earth, Canada, for their permission to reprint the article.

Comments and suggestions concerning this compendium are welcomed. Please address them to:

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SUMMARY

This compendium was prepared by the International Project for Soft Energy Paths as a part of the Decentralized Energy Studies task at the Solar Energy Research Institute. The compendium lists and briefly describes a number of studies in other industrialized nations that involve decentralized energy systems. The purpose of the compendium is to provide information about research activities in decentralized energy systems to researchers, government officials, and interested citizens. A contact person or address is given for each of the activities listed so that more information can be obtained by interested readers.

The twenty studies described vary in scope and comprehensiveness. Despite similarities in issue and energy sources, differences exist in emphasis, background assumptions, and definition of terms. Eighteen of the studies examining future energy use make several of these points: renewable energy sources, if used efficiently, can provide all or the majority of energy supplies in developed nations; large increases in end-use energy efficiency are currently cost-effective, and improvements can reduce energy consumption by as much as 90%; energy supply problems decrease as demands decrease; lifestyle changes and other social factors combined with rising energy prices can reduce energy demands substantially; and end-users should be able to provide a substantial portion of their own energy needs.

Thus, the potential for cost-effective energy savings is great, and one way these savings can be achieved is by gradually introducing renewable energy sources with currently available technologies. Existing institutional relationships involving centralized energy systems are presently inhibiting implementation of decentralized systems and research on this issue is needed.

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INTRODUCTION

1.1 PURPOSE

The purpose of this compendium is to identify and describe briefly some of the studies, that involve efforts by researchers in other industrialized nations to find alternatives to large, centralized energy systems. It is hoped that the compendium will provide an overview of the activities that are taking place in other parts of the world and will permit interested citizens and government officials in the United States to obtain more detailed information from the sources identified.

1.2 BACKGROUND

The 20 studies compiled in this compendium have been chosen on the basis of their relevance to the study of decentralized energy systems in the United States. Detailed investigations undertaken in Canada, Denmark, the Federal Republic of Germany, France, the Netherlands, Israel, Italy, Japan, New Zealand, Sweden, and the United Kingdom not only yield useful information, but also provide an analytic framework for future energy studies. This analytic framework is directly applicable to U.S. decentralized energy studies. The economic, cultural, and geographical similarities between these industrialized nations also allow U.S. energy researchers to draw upon the results of these international research efforts.

The study of decentralized energy systems represented in this compendium has been largely a synthesis effort. Each study has built upon and added to previous research—refining the methodology and modifying the assumptions to fit specific circumstances. Rather than reinventing the wheel time and time again, the researchers utilize knowledge and practical experience already gained. Some U.S. decentralized energy studies, however, have overlooked the findings and methodologies offered by the international research community. Detailed analyses of end uses of energy, the cost-effective combination of renewable energy sources, and efficiency improvements have been lacking in many U.S. efforts. Better end-use data gathering on the national, regional, state, and local levels is essential if decentralized energy research is to have an on-going policy impact.

SECTION 2.0

STUDIES

2.1 CANADIAN PROVINCIAL STUDIES

Principal Investigators:

Two per province for ten provincial level studies.

Contact:

David Brooks
Friends of the Earth/Energy Probe
54-53 Queen Street
Ottawa, Ontario, Canada K1P 5C5

Phone: (613) 231-2742

Source of Funds:

Variable by province

Budget/Level of Effort:

Variable by province

Purpose/Scope/Objectives:

The project aims to prepare a set of parallel soft energy path studies for each of the ten Canadian provinces and to develop a manual for undertaking soft energy path studies.

Location/Time Period:

The studies are set in Canada, 1975 to 2025.

Issues Addressed:

There is an emphasis on the economic and cultural aspects of Canada's energy future, especially in terms of defining Canada as a distinct entity from the United States. The following are among the economic, environmental, institutional, political, and social issues addressed: capital intensity, distribution of costs and benefits, employment, automation, labor stratification and specialization, institutional change and adaptability, ownership and control, regulations, pollution, lifestyles and values.

Concept of Decentralization:

Decentralization is defined in political and social terms more so than in technical terms; e.g., the ease in adjusting scale and decision-making to local and regional needs. Technologically, the criteria are the same as Amory Lovins' with some tendency to consider large hydro and methanol as quasi-hard sources.

Analytical Methods:

The ten province-by-province studies differ not only in style, but in some basic approaches and supply and demand assumptions. However, each of the studies loosely follow the guidelines presented in the manual for undertaking soft energy studies.

The studies focus, first, on the services (end uses) provided by energy; second, on the techniques and costs of providing those services with less energy; and third, on the techniques and costs of using renewable sources to supply the remaining energy demand. The studies utilize end-use analysis to identify energy by the sector of use (domestic, commercial, etc.); specific function within the sector (heating, lighting, etc.); and quality (low temperature heat, electricity, etc.). This analysis establishes a framework for matching end use with suitable renewable supplies.

Each of the studies chooses a date far enough in the future for capital to turn over and institutional changes to take effect. Then they "work backwards" to the present to see which technologies have to be deployed and when.

The studies accept conventional economic growth and official demographic projections, but goods and services are provided as efficiently as possible with efficiency generally defined in economic terms (maximum monetary payoff) but, in some cases, in physical terms (minimum energy consumption).

Energy Sources/Technologies

Primary focus is on conservation. Renewable energy technologies, which are selected not only for their thermodynamic characteristics but also for economic feasibility, indigenous resource availability, and least social disruption, then are considered. The following are among the renewable resources and transitional fossil fuel technologies included in the studies: solar heating and cooling, passive design, biomass (with emphasis on methanol production), geothermal, solar heat engines, wind, hydro, wave, tidal, district heating, cogeneration, fluidized bed combustion, and natural gas.

Research Product:

Alternatives. Summer/Fall 1979. Includes "A Guide to Soft Energy Studies" by David Brooks and Sean Casey; also edited versions of the Ontario, Saskatchewan, and Newfoundland studies.

Alternatives. Winter 1980. Contains edited versions of the remaining studies. Each issue is available for $2.75 from Alternatives; Trail College, Trent University; Peterborough, Ontario; Canada K9J 7B8.

Some Scenarios of Energy Demand in Canada in the Year 2025. 60 pages; April 1977; $2.00. Available in limited supply from Energy Probe; 27-53 Queen Street; Ottawa, Ontario, Canada K1P 5C5.

2.2 CANADIAN ENERGY FUTURES—AN INVESTIGATION OF ALTERNATIVE ENERGY SCENARIOS, 1974-2025

Principal Investigators:

John Robinson
Charles Figueiredo
Geoff Hare
Jim House-Holder
Tom Kerwin
Bob Noble
Naseem Syed
Marilyn Vavasour

Contact:

John Robinson or Charles Figueiredo
Workgroup on Canadian Energy Policy
Faculty of Environmental Studies
5th Floor, Scott Library
York University
4700 Keele Street
Downsview, Ontario, Canada M3J 1P3

Source of Funds:

Federal Department of Manpower and Immigration, Provincial Ministry of the Environment, and the Federal Department of Energy, Mines, and Resources.

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The study compares the federal policy implications of different "soft" and "hard" energy paths in Canada through the year 2025; suggests that energy policy making should involve a consideration of the potential and implications of demand management (i.e. conservation policies); and determines what energy policy measures would have to be instituted over the next fifty years in order to reach specific energy futures.

Location/Time Period:

The setting is Canada between 1974 and 2025.

Issues Addressed:

The study addresses the following economic, environmental, institutional, and social issues: production modes, Gross National Product (GNP) growth rates (no inclusion of economic costs), short- and long-term environmental effects, institutional change and adaptability, mandates and regulations, problems with policy formulation, lifestyle and values, and land use.

Concept of Decentralization:

Renewable energy sources.

Analytical Methods:

The analysis makes no attempt to predict likely futures; instead it gives a range of possibilities, defined in terms of energy consumption in 2025. Rather than developing a sector-by-sector model for the year 2025 (as in the Canadian Studies, see Sec. 2.1) Robinson, et al. develop an alternative "backcasting" technique in which consumption levels in the year 2025 are simply assumed and then analyzed to see what technical and policy changes would be necessary to make that result come about. Energy consumption levels are derived independently of macro-economic and demographic variables so that economic and demographic implications of each consumption level can be analyzed. On the basis of these levels, scenarios are developed, extending from the present to 2025 and embodying different supply mixes, both in terms of energy supply and demand. The supply mixes considered are: (1) conventional sources and, (2) maximum deployment of renewable resources with conventional sources making up any deficit that may occur between renewable capability and demand. End-use breakdowns are used for supply matching. The emphasis is placed on using efficiency and conservation measures to keep demand low. The implementation of solar energy is treated as a demand management measure rather than as a way of producing supplies necessary to meet projected demands.

Energy Sources/Technologies:

Renewable energy sources and "efficiency measures" are defined as demand management measures that improve the second law efficiency of an energy system without necessitating lifestyle or structural change. All measures considered technologically feasible at the present time are deployed, with no consideration given to their costs. Technologies included are: solar heating and cooling, passive design, wind, biomass (waste and plantations), hydro and tidal power.

Research Product:

Canadian Energy Futures, An Investigation of Alternative Energy Scenarios 1974-2025. August 1977; 229 pages, available from the Workgroup on Canadian Energy Policy, Faculty of Environmental Studies, 5th Floor, Scott Library, York University, 4700 Keele St., Downsview, Ontario, Canada M3J 1P3, $10.00.

2.3 SASKATCHEWAN ENERGY USE AND RENEWABLE ENERGY SUPPLY: THREE SCENARIOS FOR 2025 (CANADA)

Principal Investigators:

Deryl Thompson
Herman Boerma

Contact:

Deryl Thompson or Herman Boerma
Saskatchewan Research Council
30 Campus Drive
Saskatoon Saskatchewan, Canada S7N 0X1
Phone: (306) 664-5449

Source of Funds:

Saskatchewan Research Council (SRC) and the Saskatchewan Government

Budget/Level of Effort:

$5,000; 4 person-months

Purpose/Scope/Objectives:

The study is designed to (1) evaluate the existing data base; (2) conduct an inventory of renewable energy resources; (3) experiment with various methodologies; and (4) educate the populace and decision makers.

The report considers the physical and technical feasibility of a soft energy path; it does not include an economic analysis.

Location/Time Period:

The study concerns Saskatchewan province in Canada from 1975 to 2025.

Issues Addressed:

Production modes and lifestyle and values are the economic and social issues that are discussed.

Concept of Decentralization:

The authors share Amory Lovins' definition of decentralized (soft) energy as employing renewable resources and diverse technologies that are matched in scale and quality to end-use needs.

Analytical Methods:

The analysis of Saskatchewan's 1975 energy use was carried out in an attempt to estimate its end-use structure. 2025 energy demand projections are then made based on assumptions about population, economic growth, and energy efficiency improvements.

The domestically available supply of renewable sources is also estimated and matched with projected demands. Three scenarios are examined: (1) "business as usual" with no improvements in energy efficiency beyond what is common practice today, (2) a "technical fix" scenario in which only proven efficiency improvements are used, and (3) the efficiency improvements used in Scenario 2 with lifestyle changes that reduce the perceived needs of the population.

Energy Sources/Technologies:

The focus is on renewable sources such as: solar heating and cooling, passive design, wind, hydroelectric, and biomass (gasification, pyrolysis, and ethanol). Technological factors such as efficiency of material and energy use are also considered.

Research Product:

Saskatchewan Energy Use and Renewable Energy Supply: Three Scenarios for 2025. 80 pages, and appendices, Summer 1979; Available from SRC; 30 Campus Drive; Saskatoon, Saskatchewan, Canada, S7N 0X1. Free of charge.

2.4 DEMO-PROJECT (DENMARK)

Principal Investigators:

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Sussanne Blegaa
Erik Mosekilde

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Lyngby, Denmark
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Source of Funds:

National Research Council and Technical University of Denmark

Budget/Level of Effort:

$200,000

Purpose/Scope/Objectives:

The purpose of the Dynamic Energy Modeling (DEMO) Project, started in 1975, is to investigate and analyze future options for Denmark's energy situation. The analysis takes into account the relationship between energy consumption and developments in such areas as values, lifestyles, technologies, and world energy prices.

Location/Time Period:

The time period includes an analysis of Denmark's energy picture from 1950-1975, and analysis of 1975-2030.

Issues Addressed:

The study addresses the following economic, environmental, institutional, political, and social issues: capital intensiveness, distribution of costs and benefits, production modes, balance of trade, pollution, consumption of energy, short-term and long-term environmental effects, labor specialization and stratification, automation and unemployment, institutional change and adaptability, ownership and control, distribution of wealth, subsidies and taxes, lifestyle and values, social and cultural cohesion, population concentration, employment patterns, equity, land use, and quality of work.

Concept of Decentralization:

Decentralization involves using conservation techniques and renewable energy technologies that have relatively small environmental impact and are adaptable to local resources, control, and lifestyles.

Analytical Methods:

The study employs (1) scenario-technique assuming consistent possible future development for the whole society; (2) a system-dynamics method that keeps track of the stocks of houses, appliances, vehicles, solar collectors, etc., for three main sectors: the private household sector, the energy supply sector, and the production sector; and (3) input-output technique for analyzing the production sector. The system-dynamics method also keeps track of how much stock is utilized (e.g., 4.5 washing machine uses per week) and potential energy consumption, i.e., changes resulting from using conservation techniques.

The analysis is carried out on different background scenarios in which certain assumptions about developments in other areas of society such as technology, world economy, social structure, and personal values, are incorporated into the prognosis of future energy demand and supply. Different energy strategies, such as a strong emphasis on nuclear, renewables, or conservation, are tried out in combinations with the background scenarios. For a selected combination of strategies and background scenarios, the dynamic models calculate energy demand, energy conservation investments, employment, and so forth, thereby creating many scenarios for the whole society. See also the Husholdninger og Energi study, Methods and Techniques Section.

Energy Sources/Technologies:

The emphasis is on conserving energy and using renewable energy sources. The following sources and technologies are discussed: solar heating, passive design, wind, biomass, photovoltaics, and small-scale cogeneration. The study also discusses technological factors such as efficiency of material and energy use, scale, distribution losses, system vulnerability and reliability, safety and health.

Research Product:

Reports from the DEMO-Project:

No. 1: Danske Energimuligheder. A summarizing technical report for the entire project. Different possible developments in energy demand and supply in Denmark are analyzed. Results are presented as corresponding development graphs for selected problem areas. In Danish, final draft not released.

No. 2: Danmarks Energiforsyning-Valgmuligheder frem Til Aar 2000. Sussanne Blegaa. Study of possible developments in Denmark's energy supply to the year 2000. A wide variety of alternative developments are described. In Danish, about 250 pages, published 1977.

No. 3: Decentrale Kraft-Varmevaerker. Lars Josephsen and Benny Petersen. A technical and economic study of possibilities for incorporating in Denmark's energy supply system small cogenerating (electricity and heat) units, especially diesel engine units ranging from 0.5 MW to 10 MW. In Danish, 120 pages, published 1977.

No. 4: Husholdninger og Energi. Jørgen S. Nørgard. Study of possible future consumption patterns for private households in Denmark to the year 2030, with emphasis on energy consumption. Different assumptions about development in technical conservation measures, in economy, in energy prices, and in the general public attitude towards materials growth are used. In Danish, 400 pages, published April 1979. Forthcoming in English.

No. 5: Bolig og Varme. Jørgen S. Nørgard. Study of the development in the stock of dwellings from 1950 to 1975 and in the corresponding heat consumption. Based on this, the potential for heat conservation in the present stock is evaluated. In Danish, 73 pages, published 1977.

No. 6: Produktion og Energi. Erik Mosekilde and Niels I. Meyer. Study of the developments in energy demand, in economy, and in employment for the production sectors resulting from different assumptions about private and public consumption patterns. In Danish, final draft not released.

No. 7: Erhverv og Energiforbrug. Hans Djurhuus. Study of energy consumption in the commercial and industrial sector in the years 1950 and 1973. Emphasis is on demand for space heating, lighting, and on the potentials for conservation. In Danish, about 110 pages, published May 1979.

No. 8: Danmarks Energi paa langt Sigt-Flere Muligheder. Niels I. Meyer et al. A summarizing description of the major results from the DEMO-project. The report is aimed at a broad circle of nonexpert readers. In Danish and not yet published.

No. 9: Alternative Danish Energy Developments-A Dynamic Analysis. Niels I. Meyer et al. A condensed version of report no. 1. In English but not yet published.

A number of short papers in English describing parts of the DEMO-project are available on request.

2.5 HUSHOLDNINGER OG ENERGI (HOUSEHOLDS AND ENERGY) (DENMARK)

Principal Investigator:

Jørgen Nørgard

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DK-2800
Lyngby, Denmark
Phone: (02) 88 16 11

Source of Funds:

National Research Council and Technical University of Denmark

Budget/Level of Effort:

$100,000; 50 person-months

Purpose/Scope/Objectives:

This report is part of the DEMO-Project, the goal of which is to examine the long-term energy choices for Denmark. The report describes an investigation of possible future patterns for private household consumption (food, services, durable goods, personal vehicle transportation, etc.), with emphasis on three energy categories: heat, electricity, and transportation energy. Personal transportation is included since it is part of the household budget.

Location/Time Period:

The setting is Denmark from 1950 to 2030.

Issues Addressed:

The report discusses the choices of technologies in the short-run as they effect energy consumption, and the effect of lifestyle and social structure choices in the long-run. It also explores different paths of development and their corresponding energy usages.

The following economic, environmental, institutional and social factors are discussed: capital intensiveness, distribution of costs and benefits, production modes, relationship between lifetimes of consumer goods and economic growth, pollution, consumption of energy, short- and long-term environmental effects, labor specialization and stratification, automation and unemployment, institutional change and adaptability, ownership and control, distribution of wealth, subsidies and taxes, mandates and regulations, lifestyle and values, social and cultural cohesion, population concentration, employment patterns, equity, land use, and quality of work.

Concept of Decentralization:

Decentralization includes conservation techniques and renewable energy technologies.

Analytical Methods:

Three main scenarios are developed from the following assumptions: (1) unchanged attitudes towards economic growth and high economic growth, (2) unchanged attitudes towards material growth and low economic growth, and (3) new attitudes towards material growth (a "satiation" scenario in which the public no longer finds economic growth beneficial). Soft energy technologies are introduced as the capital stock requires replacement, and investment in soft sources and conservation techniques is made on the basis of simple marginal payback time or on assumed government codes. Energy prices in Scenario 3 are assumed to increase 2 to 3 times their 1975 level. Moderate, strong, and radical degrees of efficiency improvements are considered and explored in technical detail indicating a large range of potential energy conservation without altering lifestyles.

Energy Sources/Technologies:

Soft technologies and efficiency improvements are introduced during 1980-2000 for appliances and cars, and up to 2030 for houses. Conservation techniques and low temperature solar heating, biomass, wind-power, and photovoltaics are the energy sources and technologies included. Efficiency of material and energy use, scale, distribution losses, system vulnerability and reliability, and safety and health are among the technological factors that are included.

Research Product:

Husholdninger og Energi; in Danish, 400 pages. Available from Poyteknisk Forlag, D. T. H., DK-2800, Lyngby, Denmark. Price: 115 Danish Kr. ($21.00). Forthcoming in English.

2.6 NIELS BOHR INSTITUTE (DENMARK)

Principal Investigator:

Bent Sørensen

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Niels Bohr Institute
University of Copenhagen
17 DK-2100 Copenhagen, Denmark
Phone: 451-42 16 16

Source of Funds:

University of Copenhagen and Danish Research Council

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The Niels Bohr Institute undertakes research involving energy systems analysis, energy policy, energy planning, energy needs as they pertain to social structure, and reliability of renewable energy systems as a function of time and geographical distribution.

Location/Time Period:

The studies address different geographical areas, ranging from village to global scale. The time periods extend from the present to 2075.

Issues Addressed:

The following economic, environmental, institutional, political, and social issues are discussed: distribution of costs and benefits, competition for resources, balance of trade, adoption of economic theory to accommodate long-range economic effects, pollution, consumption of energy, environmental costs-benefits, labor specialization and stratification, institutional change and adaptability, subsidies and taxes, lifestyles and values, equity and land use.

Concept of Decentralization:

The studies define decentralization as renewable energy sources matched in scale and quality to end-use needs.

Analytical Methods:

Methodology for a Scandanavian and global study is presently being determined. Analysis will include computer simulation, model formation, and social and technical analysis.

Energy Sources/Technologies:

Research is undertaken on the following: solar heating and cooling, passive design, district heating, wind, biomass, wave, photovoltaics, and combinations of the former energy sources with storage. Efficiency of material and energy use, scale, distribution losses, diversification, system vulnerability and reliability, safety and health, and technical optimization are among the technological factors that are considered.

Research Product:

To obtain a listing of available publications write to the Niels Bohr Institute, University of Copenhagen, 17 DK-2100 Copenhagen, Denmark.

2.7 SOFT ENERGY PATH, FEDERAL REPUBLIC OF GERMANY

Principal Investigator:

Florentin Krause
H. Bossel
K. F. Muller-Reismann

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Schoenauer Str. 3
78 Freiburg
Federal Republic of Germany
Phone: (0049) 761 42099

Source of Funds:

Funding has come from a variety of foundations and public interest organizations.

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The overall objective is to analyze the potential for a comprehensive "soft" energy path for the Federal Republic of Germany. The scope includes four major areas: (1) the potential of renewables when "maximum" energy efficiency improvements have been made first, (2) the potential of conservation when comparing long-run marginal costs, (3) the degree of energy independence that can be achieved given economic growth, and (4) the feasibility of a nonnuclear transition and future.

Location/Time Period:

The Federal Republic of Germany, (FRG), a country with an unusually large fraction of GNP from industrial production, has a small service sector compared to other European countries and the United States. The term for analysis is 1973 to 2030.

Issues Addressed:

The study discusses the following economic, political, institutional and social implications of a soft energy path for FRG: capital intensiveness, distribution of costs and benefits, energy dependence, criteria for choosing a flexible supply system, comparative advantage in international trade, ownership and control, distribution of wealth, and lifestyles and values.

Concept of Decentralization:

Decentralized energy employs renewable sources and environmentally gentle technology; it features localized costs and benefits, is flexible, and matches energy quality and scale to end use.

Analytical Methods:

The study posits a technical fix (reference) scenario relying on conventional forecasts about economic growth and increased levels of consumption to the saturation point for energy services; e.g., m^2 of floor area heated. The technical fixes are introduced to improve end-use efficiency in all areas of consumption. Changes are not assumed in society or in people's lifestyles. A five-year grace period is given for efficiency improvements, and the rate at which these improvements occur (within a 30-year period) is determined by the replacement and repair rates of houses, cars, appliances, industrial equipment, etc. The scenario uses the same proportions of fuels (coal, nuclear, oil, and natural gas) that are used today, although the quantity used is based on demand once technical fixes have been implemented. Improvements are chosen from those measures that are economically attractive against the long-run marginal costs of nuclear or coal conversion systems.

Two main "variant" scenarios also are developed, representing extreme cases, and intending to demonstrate the diverse technological combinations between the extremes. The supply mix in the alternative scenarios consists of: (1) replacement of oil by coal and natural gas and no renewable sources: and (2) replacement of oil and natural gas, introducing renewables and maintaining coal (the latter for high temperature process heat only).

Approximately 70 end-uses are studied; 17 industrial sectors, 8 building types, and 12 appliances are used. End-use demand is calculated for each ten-year period. The analysis of the industrial sector also considers comparative advantages in world trade.

Energy Sources/Technologies:

Primary focus is on conservation and then a consideration of renewable resources such as: solar heating (low temperature), passive design, district heating, wind, biomass (methanol), hydro and cogeneration, and coal (used in fluidized beds) as a replacement fuel to meet high temperature requirements. Technological factors such as efficiency of material and energy use, scale, distribution losses, diversification, system vulnerability, and reliability are also considered.

Research Product:

Die Energie-Wende; in German, 200 pages. Available from S. Fisher, Verlag, Frankfort, Federal Republic of Germany. 20 dm. An English language summary of the draft report is available from the International Project for Soft Energy Paths (IPSEP); 124 Spear Street; San Francisco, CA 94105. 46 pages; $3.50.

2.8 PROJET ALTER (FRANCE)

Principal Investigators:

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Phillippe Chartier
B. Dessus

Contact:

Philippe Courrége
Groupe de Bellevue
85 Boulevard de Port Royal
75013 Paris, France

Source of Funds:

Privately funded

Budget/Level of Effort:

Groupe de Bellevue is an informal group of scientists and engineers.

Purpose/Scope/Objectives:

The study evaluates the technical potential of using renewable energy to supply all of France's long-term energy needs.

Location/Time Period:

The setting is France, post 2050.

Issues Addressed:

The following environmental, institutional, and social issues are discussed: long-term environmental effects, land use, equity, and institutional change and adaptability to decentralization.

Concept of Decentralization:

Energy applications that are on a small scale are given preference, although the study does recognize that in order to meet France's energy needs, communal-scale and some large scale (tidal plants and large hydro) projects also may be required.

Analytical Method:

2050 energy demand is evaluated on an end-use basis with the major sectors broken down, and the industrial sector further broken down into 15 subsectors. Energy supply is assessed according to France's natural resources and soft energy technologies as they exist today. No new efficiency improvements or soft technology breakthroughs are expected.

Energy Sources/Technologies:

Only presently known technologies are included. Among these are: solar heating and cooling, passive design, wind, biomass (including agro-energy complexes) tidal, hydro, underground aquifiers to store interseasonal heat, hydrogen for gaseous fuels and fuel cells. Efficiency of material and energy use and scale also are considered.

Research Product:

Projet Alter, Etude d'Un Avenir Energétique Pour la France Axé Sur le Potentiel Renouvelable, published in February 1978, 64 pages, in French, available from Librarie Syros, 9 run Borrouiee, 75015, Paris, France, 8 francs ($1.90).

2.9 TOUT SOLAIRE (FRANCE)

Principal Investigators:

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Dominique Simonnet

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Pierre Samuel
Les Amis de la Terre
14 bis, rue de l'Arbalete
75005 Paris, France
Phone: 707 2523

Source of Funds:

Public interest

Budget/Level of Effort:

$35,000

Purpose/Scope/Objectives:

This study aims to determine the amount of end-use matched energy that would be required to meet a French standard of living more comfortable than today's.

Location/Time Period:

The study is set in France from the present to 2050.

Issues Addressed:

The economic, environmental, institutional and social issues considered are: material growth, product durability, capital intensity, pollution, land-use effects from biomass, consumption of energy, long-term environmental effects, safety and health, labor specialization and stratification, distribution of wealth, incremental implementation plans, ownership and control, lifestyle changes, decentralized production, population concentration, and equity.

Concept of Decentralization:

Only renewable energy sources and proven technologies are included. No technical breakthroughs are expected. Some lifestyle changes, such as increased use of public transportation, are assumed. More durable goods are also assumed.

Analytical Methods:

Using the data base from Projet Alter, this study develops two scenarios: (1) high alternative, with greater energy use; and (2) stable state, with lower energy use. Both Tout Solaire and Projet Alter utilize end-use analysis with a 5-sector breakdown and then a further breakdown of the industrial sector into 15 subsectors. Technologies are not assessed in economic terms.

Energy Sources/Technologies:

Diversification, efficiency of material and energy use, and system vulnerability and reliability are among the technological factors taken into account. The following energy sources are also included: solar heating and cooling, passive design, wind, biomass (including plantations), tidal, hydro, hydrogen (obtained by electrolysis in solar and wind electric plants) and heliogeothermal (underground aquifers to store inter-seasonal heat).

Research Products:

Tout Solaire, published by Pauvert. 32 francs ($7.50), 100 pages, May 1978. Available from Les Amis de la Terre, 14 bis, rue de l'Arbalete, 75005 Paris, France.

2.10 ENERGIEBELEID MET MINDER RISICO (THE NETHERLANDS)

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Source of Funds:

N/A

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The study investigates the possibilities of further industrial growth in the Netherlands against a background of increasing fuel and raw material scarcity and environmental degradation.

Location/Time Period:

The setting is the Netherlands from 1975-2025.

Issues Addressed:

The study includes a discussion of the following economic, environmental, institutional, and social issues: distribution of costs and benefits, competition for resources, production modes, long-term effects, environmental costs-benefits, labor specialization and stratification, automation and unemployment, institutional change and adaptability, ownership and control, and employment patterns.

Concept of Decentralization:

Decentralized sources are defined as what can be continued in the future; i.e., renewable, available, and environmentally benign.

Analytical Methods:

The authors use dynamic modeling. A major assumption is that oil prices will gradually increase to twice the 1975 price by 2000, resulting in a 40% drop in national oil consumption and motivating conservation and renewable energy investments.

Energy Sources/Technologies:

All available "soft" sources and technologies that can be applied to the Netherlands, among which are: solar heating and cooling, passive design, district heating, wind, and biomass. The following technological factors are also discussed: efficiency of material and energy use, scale, and system vulnerability and reliability.

Research Product:

Energiebeleid met Minder Risico (Energy with Less Risk), 1977 report. The update has recently been completed, 70 pages, in Dutch, $4.00, Cenbrum voor Energiebesparing, Schiedamse vest 42 E, Rotterdam 3011 BA, the Netherlands.

2.11 SOFT ENERGY PATH (ISRAEL)

Principal Investigator:

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Source of Funds:

Small grants, including a grant from IPSEP.

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The study represents a preliminary exploration of a soft energy path for Israel. The study surveys the technological work presently underway in Israel, the present use of renewable energy sources, the potential for greater use of renewable sources, and national policy concerning the implementation of conservation and renewable sources.

Location/Time Period:

The study focuses on Israel from the present to 2025.

Issues Addressed:

The following economic, institutional and political issues are briefly addressed: capital intensiveness, production modes, balance of trade, specific hardware costs, institutional change and adaptability, subsidies and taxes, mandates and regulations, and system vulnerability and reliability.

Concept of Decentralization:

The study focuses upon energy sources that are matched in quality to end use, indigenous (may require cooperation between neighboring countries), and environmentally benign. Also included is a match in scale to cultural needs; e.g., a kibbutz biomass project.

Analytical Methods:

The technique used is end-use analysis, calculating energy usage for the years 2000 and 2025. Unfortunately this preliminary sketch of Israel's energy future must be brief for there is very little end-use data available, and no serious efforts yet have been made to develop a data base for conventional forecasts or scenarios. Therefore, "back-of-the-envelope" calculations are used in this assessment.

Israel has the additional problem of defining exactly what energy sources are indigenous, as the national boundaries are in a state of flux.

Energy Sources/Technologies:

Solar ponds (including floating ponds in large lakes and bays) with Rankine cycle heat engines, agricultural waste and other biomass, solar powered irrigation pumps, absorption chillers, solar assisted heat pumps, and cogeneration are among some of the more innovative Israeli projects being considered. Also considered is the efficient use of material and energy.

Research Product:

Solar Energy: the Main Soft Energy in Israel. 28-page survey, $2.00; available from IPSEP; 124 Spear St.; San Francisco, CA 94105.

2.12 THE END USES OF ENERGY IN ITALY

Principal Investigators:

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Source of Funds:

Government funds

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The study identifies end-use energy needs in the various sectors of energy use to provide a preliminary framework for national energy policy decisions.

Location/Time Period:

The setting is present day Italy; most of the surveys refer to statistical data from 1974 and 1975. However, this is to determine end-use needs so that energy quality can be more appropriately matched in the future.

Issues Addressed:

The study considers end-use energy requirements for Italy.

Concept of Decentralization:

The study focuses on matching energy quantity and quality to end-use requirements.

Analytical Methods:

End use is separated into two categories: thermal and nonthermal. Thermal end uses are further broken down into temperature ranges: low, medium, and high with high being 250°C rather than 600°C. The nonthermal uses refer to final demand for mechanical energy, which is broken down into uses for transportation and uses for electricity. The sectors are disaggregated as follows: industry, agriculture and fishing, residential and commercial, and transportation. Of these, industry is disaggregated further into 10 subsectors.

Energy Sources/Technologies:

Since the purpose of the study is to lay the groundwork for subsequent studies on end-use efficiency technologies and distributed renewables, the energy sources are unspecified.

Research Products:

A two-volume executive summary, The End-Uses of Energy in Italy, was published July 1978. It is available in English and Italian from Entè Nazionale Idrocarburi, Piazzale Enrico Mattei, 1, 00144 Roma, Italy. More exact analyses are contained in appendices. (Italian only): Definizioni Alternative dell'Energia Primaria: Sue Implicazione Per Una Corretta Valutazione Della Situazione Energetica Nazionale, 58 pages; Flusso dell'Energia Per L'Italia Dal Punto Di Vista Dell'Energia Derivata Per Usi Finalli, 99 pages.

2.13 SARDINIA 2010 (ITALY)

Principal Investigators:

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Source of Funds:

House Committee of the Italian Radical Party originally funded the Sardinia study. The National Council of Research will continue to fund this project.

Budget/Level of Effort:

$40,000 for the Sardinia study

Purpose/Scope/Objectives:

The study examines the feasibility of a distributed energy system, and analyzes the institutional implications of the transition.

Softec is also undertaking research in the following areas: low energy systems and technologies in underdeveloped areas of Italy, energy conservation in the residential sector, energy self-sufficiency in agriculture, energy efficient schools, solar energy standards and regulations, energy conservation measures and regulations, and regional and national energy policy.

Location/Time Period:

The setting is the island of Sardinia, Italy from 1980-2010.

Issues Addressed:

The study addresses the following economic, environmental, institutional, and social issues: capital intensiveness, distribution of costs and benefits, competition for resources, production modes, balance of trade, consumption of energy, short-term effects, environmental costs and benefits, labor specialization and stratification, institutional change and adaptability, ownership and control, distribution of wealth, subsidies and taxes, mandates and regulations, lifestyle and values, social and cultural cohesion, population concentration, employment patterns, equity, and land use.

Concept of Decentralization:

Decentralization is discussed in terms of indigenous renewable energy sources that are matched in quality and scale to end-use needs, are environmentally benign, and can be locally or regionally controlled.

Analytical Methods:

The two main 2010 scenarios use technological efficiency, per capita GNP, and population as the basis for determining energy demand. No technological breakthroughs are assumed for 2010. Scenario 1 uses conventional centralized energy sources to meet the projected demands, whereas in Scenario 2 decentralized renewable sources are utilized with one exception—the use of oil for a liquid fuel shortfall in the transport sector. The shortfall is dealt with in a derivation of Scenario 2 by using forms of electric transport.

Rather than working from a highly data oriented mathematical model, a general assessment of Sardinia's energy future is made (partially owing to a poor data base), the intention of which is to identify the target areas where transitional problems would most likely occur. Due to the small geographic area being studied, these areas could then be investigated in greater detail than in the national studies.

Energy Sources/Technologies:

The study focuses upon conservation and renewable sources that are presently in use today, such as: solar heating and cooling, passive design, wind, hydro, biomass, photovoltaics, geothermal, cogeneration and coal fluidized beds. Technological factors such as efficiency of material and energy use, scale, distribution losses, diversification, and system vulnerability and reliability are also considered.

Research Product:

Sardinia 2010, published June 1979, 350 pages, in Italian. Limited availability from Dr. Lorenzo Matteoli, Instituto di Technologia dell'Ambiente Construito, Facolta'd Archittura, viale P.A. Mattioli 39, Torino, Italy, $20.00. An English summary is available from IPSEP. 4 pages; $.75.

2.14 SOFT ENERGY FOR JAPAN

Principal Investigator:

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Source of Funds:

Private, independent sources

Budget/Level of Effort:

Total budget figure is not available, as work is still in progress; 24 person-months

Purpose/Scope/Objectives:

The study attempts to establish an energy plan for Japan, concentrating on energy conservation and energy supply systems using indigenous, renewable sources. It characterizes a soft-energy Japan in the year 2000.

Location/Time Period:

The setting is Japan from the present to the year 2000.

Issues Addressed:

The study explores the following economic, environmental, institutional, and social factors: capital intensiveness, competition for resources, production modes, pollution, short- and long-term environmental effects, institutional change and adaptability, ownership and control, subsidies and taxes, lifestyle and values, employment patterns, and land use.

Concept of Decentralization:

Decentralization is defined as renewable energy, matched in quality and scale to end use, having minimal environmental effects, coupled with citizen participation in creating regionally self-sufficient energy systems.

Analytical Methods:

Research is presently underway on the thermodynamic structure of end use energy, the availability of renewable energy forms, annual utilization factors, costs, lead times, and net energy outputs. Efficiency improvements of 60% to 80% are assumed by 2000. Energy use is broken down into heat, electricity, and portable liquid fuels required in the following sectors: household, iron and steel industry, other industry, agriculture, transport, and energy conversion. Introduction of soft technologies is assumed to be completed by 2000.

Energy Sources/Technologies:

The major technologies considered are solar heating and cooling, passive design, wind, biomass, tidal, wave, hydro, geothermal, and photovoltaics. Efficiency of material and energy use, distribution losses, diversification, system vulnerability and reliability, safety and health, and net energy are among the technical factors considered.

Research Product:

Soft Energy Paths for Japan. 100 pages, Draft.

2.15 EARTH RESOURCES FOUNDATION (NEW ZEALAND)

Principal Investigators:

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Source of Funds:

Government of New Zealand

Budget/Level of Effort:

$10,000

Purpose/Scope/Objectives:

The study examines legal, institutional, and cultural barriers to the full implementation of soft energy technologies in New Zealand.

Location/Time Period:

The setting is present day New Zealand.

Issues Addressed:

Among the economic, institutional, and social issues addressed are: distribution of costs and benefits, competition for resources, production modes, balance of trade, labor specialization and stratification, institutional change and adaptability, ownership and control, subsidies and taxes, mandates and regulations, and social and cultural cohesion.

Concept of Decentralization:

The study follows the Lovins' definition: renewable, diverse, matched in scale and quality to end use, and environmentally benign.

Analytical Methods:

Interviews were conducted with users, manufacturers, architects, builders, real estate agents, government researchers and administrators, university and private researchers, and other interested parties. Over 100 interviews were carried out in New Zealand, plus a number in the United States and Canada. These are supplemented by an investigation concerning specific legal barriers.

Energy Sources/Technologies:

Active solar space and water heating, passive design, methane digesters, gasifiers, micro hydro (to 100 kW), small wind (to 100 kW), solid fuel burners, and geothermal are the specific technologies addressed. Also considered are the following technological factors: efficiency of material and energy use, scale, distribution losses, and diversification.

Research Product:

Paper was presented 16 May 1979, to Fourth New Zealand Energy Conference held in Auckland. Available from Earth Resources Foundation, no cost.

2.16 SOLAR SWEDEN

Principal Investigators:

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Source of Funds:

Government of Sweden, also from the Secretariat for Future Studies for the Solar Sweden report.

Budget/Level of Effort:

$160,000/year

Purpose/Scope/Objectives:

The study assesses the potential of domestic renewable energy sources to meet Sweden's energy needs and identifies problems that could arise if Sweden were to aim its energy policy toward using only domestic renewable energy sources.

Location/Time Period:

The setting is Sweden from 1975 to 2015.

Issues Addressed:

The study examines the feasibility of basing Swedish energy supply completely on renewable energy sources, and describes the organizational characteristics of such a system. The following economic, environmental, institutional, and social issues are included: capital intensiveness, distribution of costs and benefits, competition for resources, production modes, balance of trade, pollution, consumption of energy, short- and long-term environmental effects, environmental costs-benefits, labor specification and stratification, automation and unemployment, distribution of wealth, subsidies and taxes, mandates and regulations, social and cultural cohesion, population concentration, employment patterns, equity, and land use.

Concept of Decentralization:

Decentralization is defined in terms of domestic, diversified renewable energy sources that are matched in quality to end use.

Analytical Methods

The study assumes doubling of the 1975 production level of goods and services by the year 2015. It then estimates the magnitude of indigenous renewable energy sources available to meet end-use requirements for 2015. The rate of introduction and the costs of renewable energy systems are based on what can be foreseen for the 1980s (using government agency estimates for efficiency improvements and more conservative estimates for the introduction of soft technologies). Neither 2015 energy costs or investments are calculated in the traditional Kr/kWh ($/kWh), since such calculations are dependent upon the structure of the capital market, discount rates, etc. Instead, energy costs or investments are calculated according to the labor necessary to produce and run the system—with labor, not money, being society's resource.

Energy Sources/Technologies:

The following energy sources and technologies are discussed: solar heating and cooling, passive design, district heating, cogeneration, wind, biomass (marine and terrestrial plantations included), hydro, ocean thermal, photovoltaics, technology mix, and solar cells. Technological factors such as distribution losses, safety and health also are taken into account.

Research Product:

Solar Sweden, 126 pages, December 1977, available from the Secretariat for Future Studies, Swedish Information Service; 825 Third Ave; New York, NY 10002, no cost. IPSEP will announce the availability of work in progress.

2.17 BEIJER INSTITUTE (SWEDEN)

Principal Investigator:

Lars Kristoferson

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Source of Funds:

Kjell and Marta Beijer Foundation, as well as various other private sources for specific project work.

Budget/Level of Effort:

N/A

Purpose/Scope/Objectives:

The institute conducts research in energy and human ecology. The program elements selected for investigation are: (1) a feasibility study for carrying out an impact evaluation of European energy development, (2) impact assessment methodologies for energy options, (3) environmental standards and safety and technical design criteria, (4) institutional aspects of the introduction of new energy systems, and (5) improved energy utilization in developing countries.

Location/Time Period:

The location depends on the specific study. Sweden, Europe, developing countries, and a global study are presently underway. The time period also varies according to the particular study.

Issues Addressed:

The studies address the following economic, environmental, institutional, and social issues: distribution of costs and benefits, competition for resources, balance of trade, global socio-economic impacts, pollution, consumption of energy, short- and long-term environmental effects, institutional change and adaptability, ownership and control, distribution of wealth, subsidies and taxes, mandates and regulations, lifestyles and values, social and cultural cohesion, equity, and land use.

Concept of Decentralization:

Decentralization is defined as ecological use of resources. Specific criteria depend upon the area under study.

Analytical Methods:

In each of the areas listed previously the intention is to make a scoping study that reviews the research area, highlights knowledge gaps, and, where appropriate, plans a research study to be carried out by the Beijer Institute or in collaboration with another organization. Research primarily is concerned with long-term issues of international importance.

The research method includes a review and evaluation by an international meeting of experts to determine if further research is suitable. Other methods depend on the specific study. Some studies, e.g., Sweden, utilize end-use analysis.

Energy Sources/Technologies:

Both hard and soft sources are assessed. The specific sources depend on the project. The following are some of the technologies considered: solar heating and cooling, biomass, wind, hydro, and storage systems. Scale, safety, and health are other technological factors discussed in the studies.

Research Product:

A listing of publications is available from the Beijer Institute.

2.18 MALTE 1990 (MOVEMENT'S ALTERNATIVE ENERGY PLAN) (SWEDEN)

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Source of Funds:

Swedish Energy Commission and the Swedish Government

Budget/Level of Effort:

$85,000; 50 person-months

Purpose/Scope/Objectives:

The purpose of the study is the formulation of a complete energy usage and supply plan for Sweden. The plan is designed as an alternative to the existing official energy plans, most notably the Swedish Energy Commission's plan. Characteristics of Swedish energy use and supply through the year 2000, as well as how society should develop both materially and qualitatively, are included in the plan.

Location/Time Period:

The study is set in Sweden, 1978-1990-2000.

Issues Addressed:

The following economic, environmental, institutional, and social issues are discussed in the study: production modes, pollution, short- and long-term environmental effects, labor specialization and stratification, automation and unemployment, institutional change and adaptability, subsidies and taxes, mandates and regulations, lifestyle and values, social and cultural cohesion, community planning, employment patterns, equity, land use (including local food production) and quality of work.

Concept of Decentralization:

The study assumes that Sweden's energy supply will be based primarily on "socially advantageous" renewable energy sources.

Analytical Methods:

The level of disaggregation is as follows: industry, transport, housing, agriculture, and services (which are broken down into official and commerce). A more detailed analysis is also performed within the industrial sector. The major industries studied are: pulp and papermill, steel, and chemical and cement. Assumptions about future industrial growth incorporate qualitative judgments. Industrial growth is assumed to be limited by social and environmental factors.

Energy Sources/Technologies:

The study focuses on renewable sources primarily, phasing out nuclear by 1985, and using as little coal and oil as possible through the year 2000. The energy sources included are: solar heating and cooling, passive design, district heating, wind, and biomass for industrial process heat, cogeneration and transportation. The technological factors addressed are: efficiency of material and energy use, distribution losses, diversification, system vulnerability and reliability, and safety and health.

Research Product:

MALTE, 800 pages, 90 Kr ($21.50), may be obtained from Miljoforbundet, Box 51 S-751, 03, Uppsala, Sweden. A 64-page general report is available for 6 Kr ($1.50).

2.19 A LOW ENERGY STRATEGY FOR THE UNITED KINGDOM

Principal Investigators:

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Gerald Foley
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Source of Funds:

Ford Foundation

Budget/Level of Effort:

$150,000; 80 person-months

Purpose/Scope/Objectives:

The objective is to show policy makers what possibilities exist for a conservation-oriented energy future in the United Kingdom. The study examines a technical fix scenario for the United Kingdom over a period from 1975 to 2025, assuming reasonably vigorous government policies for energy conservation.

Location/Time Period:

United Kingdom; the time period is 1975-2000-2025

Issues Addressed:

The study addresses the following economic, environmental, institutional, political and social issues: capital intensiveness, distribution of costs and benefits, consumption of energy, short- and long-term environmental effects, subsidies and taxes, mandates and regulations, lifestyle and values, and land use.

Concept of Decentralization:

Neither decentralized or soft characteristics are featured explicitly in the scenario as driving criteria. However, most of the energy conserving technologies in the study are relatively small-scale end-use devices, which either reduce the amount of energy needed for a given task (home insulation) or provide that energy using less fuel (better furnaces).

Analytical Methods:

A key element of the scenario is a disaggregated "bottom up" methodology. Macroeconomic forecasts are found to be inadequate guides to energy futures because they ignore the likely role of policy-induced changes and natural saturation effects in energy demand. A bottom up, disaggregated approach, however, takes both into account.

Assumptions about energy-use growth are generous, so as to avoid solving the energy problem through austerity. National energy end-uses are broken down into 400 components for the baseline year (1975 or 1976). The economy grows along conventional lines. In the low case, the real gross domestic product (GDP) doubles; in the high cases, real GDP triples by 2025. Future energy needs are calculated according to energy needs per unit activity for separate fuels. To get total fuel consumption, end-uses and fuels are then combined. Virtually all of the technical improvements assumed are based either on those being introduced now, because they are economically attractive today or on those improvements being developed with a view to mass manufacture because they are expected to become economically attractive. The basic economic test applied to proposed marginal investments is 1976 energy prices doubling in real terms by 2000, and tripling by 2025, with some differences between fuels. A 10% discount rate is used on technologies that were costed.

Energy Sources/Technologies:

The sources and conversion technologies considered are those currently in wide use. In a few cases, new technologies, which are at the advanced prototype stage now, are also included. To maximize its political impact, the study assumes only minor contributions from renewable sources. District heating, heat pumps, waste heat recovery, biomass, solar heating, storage, wind, wave and hydro are the major nonconventional technologies considered. Efficiency of material and energy use, distribution losses and diversification are among the technological factors considered.

Research Product:

A Low Energy Strategy for the United Kingdom, 259 pages, $16.00. Available from the International Institute for Environment and Development, 10 Percy Street, London, England W1P ODR. Available in U.S. from the Humanities Press, Atlantic Highlands, NJ 07716, $18.75.

2.20 LOW ENERGY SCENARIOS FOR THE UNITED KINGDOM, 1975-2025

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Source of Funds:

Private and government sources

Budget/Level of Effort:

$40,000; 18 person-months

Purpose/Scope/Objectives:

To examine the transitional paths and end states for at least two different patterns of social and economic development over the next fifty to seventy-five years in the United Kingdom. A technical fix conservation scenario and a conserver society scenario are under construction.

Location/Time Period:

The United Kingdom; the time period extends from the present to 2050.

Issues Addressed:

The following economic, institutional, and social circumstances surrounding low-energy use in the United Kingdom are discussed: capital intensiveness, institutional change and adaptability, subsidies and taxes, mandates and regulations, lifestyle and values.

Concept of Decentralization:

The study focuses on renewable energy sources that can be technically matched in scale and quality to end use.

Analytical Methods:

The study draws upon many previously published energy systems studies, to present a list of diverse means for improving efficiency in about 150 categories of energy use and for changing the mix of energy carriers to match particular end-use needs more closely.

Energy Sources/Technologies:

The study assumes a steady decline in the use of coal, oil, and gas; a rapid fading of nuclear power; and rapid growth in a diverse mix of soft systems with solar heat and biomass fuels as the largest components. Technologies included are those that are in common use in other countries at the demonstration stage, or, in a few cases, at an advanced stage of development.

The study covers the following energy sources and technologies: solar heating and cooling, passive design, wind, biomass, geothermal, hydro, tidal, and district heating using renewables. Technological factors such as efficiency of material and energy use, scale, and distribution losses are taken into account.

Research Product:

A Technical Fix report and a Conserver Society report are being written. IPSEP will announce the availability of both reports.

SECTION 3.0

CONCLUSIONS AND RECOMMENDATIONS

The scope and comprehensiveness of the twenty studies are highly variable. For instance, many of the studies include the same "issues addressed" and "energy sources" (see Tables 3-1 and 3-2) but the approaches differ with respect to emphasis, background assumptions, and even definition of terms. For the eighteen studies that examine future energy use, each makes several of the following points:

- With efficient use of energy, renewable energy sources can supply the majority, if not the totality, of energy supplies in developed nations at real energy prices that double or triple by 2025 (1975 prices). This appears true even in harsh climates with oil dependent industrial economies; e.g., Sweden or the Federal Republic of Germany.
- Large increases in end-use energy efficiency are cost-effective at present prices. Some reports show that cost-effective end-use efficiency improvements can reduce energy consumption (per capita, per unit of amenity, or per unit of output) to as much as 90%. This has been demonstrated by highly disaggregated analyses of end-uses. Such analyses consistently show larger potential for efficiency improvements than can be detected from conventional analyses of more aggregated data.
- As energy use demands decline due to end-use efficiency improvements, energy supply problems subsequently decrease.
- Lifestyle changes, influenced by social factors, and rising energy prices can substantially reduce demands for energy. Such changes are already discernible in end-use energy studies.
- When energy efficient capital stock is in place, many end-users of energy will be able to provide a substantial portion of their own energy needs from renewable energy sources that are directly available to them.

The previous points indicate a large potential for cost-effective energy savings, with large attendant social benefits. The studies indicate that these savings can be achieved with currently available technologies that complement the gradual introduction of renewable energy sources. Barriers seem to lie largely in institutional relationships which presently inhibit the implementation of decentralized energy systems. There has been little research on the practical issues of implementation; these studies suggest that such research is critically needed.

The use of biomass as an energy source is a pressing supply-oriented area in which further research should be undertaken. Land-use conflicts and ecological impacts require further investigation. Emphasis should be placed on the hazards that could result from energy plantations. In view of a potential liquid fuels short-fall, research efforts directed at ways to lower transport sector energy demand, i.e. end-use efficiency improvements, would be helpful.

Determining the impact of energy use in industrialized nations on the world economy—specifically in developing countries—is a third area requiring further research. As the scope of many decentralized energy studies is mainly limited to domestic impacts, the relationships among countries has not been adequately addressed.

As noted in the introduction, U.S. energy data on the local, state, regional, and national levels are inadequate. This is particularly true with respect to end-use energy accounting, biasing the impacts of energy policies and the priorities of energy research on to energy supply rather than demand reduction measures.

In conclusion, international decentralized energy studies can provide an analytic framework and information base for studies to be undertaken in the United States. They can also help determine areas of emphasis for further research. These benefits can be applied not only to national studies, but also to local, state, and regional studies.

Table 3-1. ECONOMIC, ENVIRONMENTAL, INSTITUTIONAL/POLITICAL, SOCIAL ISSUES ADDRESSED

Study \ Issues	Capital Intensiveness	Distribution of Cost and Benefits	Competition for Resources	Production Modes	Balance of Trade	Pollution	Consumption of Energy	Short-Term Effects	Long-Term Effects	Environmental Costs/Benefits	Lifestyle and Values	Social and Cultural Cohesion	Population Cont.	Employment Patt.	Equity	Land Use	Labor Specialization/Stratification	Automation and Unemployment	Institutional Change and Adaptability	Ownership/Control	Distribution of Wealth	Subsidies/Taxes	Mandates/Regulations	Other/Specified See Reports
Canada[a]	X	X				X	X				X			X			X	X	X	X			X	
Canada[b]				X				X	X		X					X			X				X	X
Canada[c]				X							X													
Denmark[d]	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Denmark[e]	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Denmark[f]		X	X		X	X	X			X	X				X	X	X		X			X		
FRG	X	X		X							X									X	X			
France[g]									X						X	X			X					X
France[h]	X			X		X	X		X		X		X		X	X	X			X	X			X
Holland		X	X	X					X	X				X			X	X	X	X				
Israel	X			X	X														X			X	X	
Italy[i]	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	
Italy[j]																								
Japan	X		X	X		X	X	X	X	X	X			X		X			X	X		X		
New Zealand		X	X	X	X							X					X		X	X		X	X	
Sweden[k]	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X	
Sweden[l]				X		X		X	X	X	X	X		X	X	X	X	X	X			X	X	
Sweden[m]		X	X		X	X	X	X	X	X	X	X			X	X			X	X	X	X	X	
UK[n]	X	X					X	X	X		X					X						X	X	
UK[o]	X										X		X			X			X			X	X	

[a]D. Brooks
[b]Robinson
[c]Thompson
[d]DEMO Project

[e]Nørgard/Hshlds
[f]Sørensen
[g]Projet Alter
[h]Tout Solaire

[i]Sardinia
[j]End-Uses Italy
[k]Solar Sweden
[l]MALTE 1990

[m]-Beijer Inst.
[n]Gerald Leach
[o]David Olivier

Table 3-2. ENERGY SOURCES/TECHNOLOGIES AND TECHNOLOGICAL FACTORS ADDRESSED

Study \ Technical Factors	Efficiency of Material and Energy Use	Scale	Distribution Losses	Diversification	System Vulnerability/ Reliability	Safety/Health	Conservation	Solar Heating and Cooling	Passive Design	Cogeneration	District Heating	Wind	Biomass	Wave or Tidal	Hydro	Ocean Thermal	Photovoltaics	Geothermal	Technology Mix	Other/Specified See Reports
Canada[a]	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X		X	
Canada[b]	X		X				X	X	X			X	X	X	X					
Canada[c]	X						X	X	X			X	X		X					X
Denmark[d]	X	X	X		X	X	X	X	X	X		X	X				X		X	
Denmark[e]	X	X	X		X	X	X	X				X	X				X		X	
Denmark[f]	X	X	X	X	X	X	X	X			X	X	X	X			X		X	X
FRG	X	X	X	X	X		X	X	X	X	X	X	X		X					X
France[g]	X	X					X	X	X			X	X	X	X					X
France[h]	X				X	X	X	X	X			X	X	X	X					X
Holland	X	X			X		X	X	X		X	X	X							
Israel	X				X		X	X	X	X			X						X	X
Italy[i]	X	X	X	X	X		X	X	X	X		X	X		X		X	X	X	
Italy[j]	X						X													
Japan	X		X	X	X	X	X	X	X			X	X	X	X		X	X		
New Zealand	X	X	X	X			X	X	X			X	X		X			X		
Sweden[k]	X	X				X	X	X	X	X	X	X	X		X	X	X		X	X
Sweden[l]	X		X	X	X	X	X	X	X	X	X	X	X							X
Sweden[m]	X	X				X	X	X				X	X		X					X
UK[n]	X		X	X			X	X		X	X	X	X	X	X				X	X
UK[o]	X	X	X				X	X	X	X	X	X	X	X	X			X	X	

[a]D. Brooks
[b]Robinson
[c]Thompson
[d]DEMO Project
[e]Nørgard/Hshlds
[f]Sørensen
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[m]Beijer Inst.
[n]Gerald Leach
[o]David Olivier

APPENDIX

A GUIDE TO SOFT ENERGY STUDIES

Reprinted with permission from the Summer/Fall 1979 issue (Vol. 8, Nos. 3&4) of Alternatives, a quarterly journal available from Alternatives, c/o Trent University, Petersborough, Ontario, Canada K9J 7B8. Subscriptions: $10/yr ($12 outside North America).

Introduction

Thanksgiving weekend of 1978 brought some 20 environmentalists and energy researchers together at Trent University in Peterborough, Ontario, under the sponsorship of Friends of The Earth, Canada, to organize a set of parallel soft energy path studies for each of the ten Canadian provinces. Carrying bulky briefcases and crafty calculators, participants (see Appendix I) arrived from all parts of the country except Newfoundland, which maintained tradition and joined later, and the Territories, which were deemed to be special cases.[1] Together with Amory Lovins, the founding father of soft energy path (SEP) studies, the workshop reviewed the principles and practices of SEP analysis, and then focused on the approach, format and timing for the provincial SEP studies.

A Guide to Soft Energy Studies

by David Brooks and Sean Casey

Historically, Canada, as other industrial nations, has followed energy policies based on promotion of ever greater consumption and ever greater reliance on fossil fuels and centrally generated electricity. Now these twin pillars of conventional energy policy are cracking with age. A long litany of common problems was voiced by all participants: electrical over-capacity stimulating provincial competition for the same American markets; start and stop conservation policies that never do more than work on the fringe of the problem; governments that speak of "investments" in energy development but "costs" of conservation; few opportunities for public participation in what should be political decisions on energy policy; hydro dominance of many provincial energy policies; inadequate funding of renewable energy projects; and discriminatory subsidies of many kinds that promote energy production rather than energy conservation and nonrenewable rather than renewable sources of supply.

Yet there are sunny spots on this gloomy hard path horizon that suggest increasing acceptance of soft path ideas (and ideals). For example, 50% of all households in Nova Scotia have undertaken some form of retrofitting; a solar consortium has been established on Prince Edward Island; the White Paper published by the Québec Ministry of Energy is innovative in some ways; the Federal government has announced a set of renewable energy programs and has greatly increased R & D for renewables; and Royal Commissions as diverse as Berger on the MacKenzie Valley[2] and Porter in Ontario[3] have cast doubt on the whole growth ethic as applied to energy.

With frequent and wistful glances at the canoes gliding on a sparkling Otonabee River, the workshop began. The weakness of traditional energy studies was apparent, as was the imperative need for a new approach. The Universe became the topic! Participants speculated about energy consumption for new industrial plants, debated the use and abuse of discount rates, argued about distinguishing backcasting from forecasting, and disputed cost data — "But you can't buy a solar collector for under $100 a square yard in Nova Scotia!" Munching an apparently unlimited supply of delicious Ontario fruit, people resisted standardization into a quick single study format, but agreed to some national standards.

What follows is an attempt to capture, condense and articulate the often complex, sometimes heated debates that occured as participants worked towards common goals, principles and methods. This guide consists of three chapters that provide the basis for the province-by-province studies. Chapter One describes the nature of a soft energy **study**, which has to be narrower than that of a soft energy **path**. (It is assumed that readers of this document are broadly familiar with the characteristics and potential of soft energy paths; references and examples are found in Appendixes II and III). Chapter Two describes the methods used for SEP studies. And Chapter Three provides a preliminary manual for those engaging in SEP studies. Following the guide, in this and the next issue of **Alternatives** are the ten provincial studies. Each of the participants agreed to provide a first draft of the provincial study within four months. These studies were then reviewed by Christopher Conway of Energy Probe to ensure that assumptions and methods were reasonably compatible. On the basis of this review, the provincial studies were revised once more and then submitted for publication.

The reports published here are only the start of a process. Each of the participants agreed to do more than prepare a four-month study. Each agreed to publicize the results of his/her own study so as to expand the political base for soft energy paths and also to seek ways to undertake more detailed provincial studies. Expanded studies have already begun in several provinces.

The organization of such a national workshop required the efforts of many people and groups. Key were Beatrice Olivastri of the National Survival Institute in Toronto, Dana Silk of the Community Planning Association of New Brunswick, and Joseph Perkowski of Petro Canada. The Federal Office of Energy Conservation provided financial support.

1

What Is a Soft Energy Path Study?

A soft energy study is an analysis of the potential in a specific society, with explicit social and economic characteristics, for keeping energy demands within the bounds that can be supplied by renewable forms of energy (or at least by forms that are relatively benign from an environmental point of view and relatively easily controlled from a political one). This means that a soft path study must focus, first, on the services provided by energy; second, on the techniques for and costs of providing those services with less energy; and, third, on the techniques for and costs of using renewable sources to supply whatever energy is demanded. In addition, most soft path studies will consider the transition from our existing hard energy paths to the soft alternative.

Ironically, SEP studies have in recent years become much "harder" (in terms of the depth and precision of the analysis) than hard path studies. It is an unfounded assumption that there is good analytic back-up for the hard energy paths still being pursued by almost all countries in the world. Apart from the projections that all too commonly pass for energy analysis, there will in many cases be no hard energy path studies to compare with the soft path studies being promoted by Friends of the Earth groups throughout the world. This gives all the more reason to pursue soft path studies further and to elaborate on their implications. There will always be loose ends and aspects that cannot (and likely should not) be quantified, but the "harder" are the soft path studies, the stronger will be their pursuasive power and the greater their influence on policy.

Hard and Soft Energy Paths

The key elements of a soft energy path have been defined by Amory Lovins.[4] Soft Energy Paths combine a prompt and serious commitment to efficient use of energy; deployment of a diverse collection of renewable energy sources that are matched in scale and in quality to end-use needs; and interim use of transitional fossil fuel technologies. Soft energy paths seek to keep energy consumption within levels that will promote and maintain both an adequate standard of living and an improving quality of life. (Standard of living is precisely defined by per capita monetary income; quality of life is not entirely quantifiable but incorporates a host of factors that reflect the pleasure individuals and groups draw from life.) The goals are a sustainable economy and a healthy environment, together with decentralized decision making, all of which are undermined by excessive levels of energy consumption.

Hard energy paths contrast sharply with soft ones. Their key, yet typically implicit, element is to extend energy consumption, for growing energy demand is accepted and justified as indicative of rising living standards. To deliver this quantity and quality of energy, a series of projects are forecast as necessary to meet "requirements". Inevitably, they depend upon investments in frontier oil and gas, nuclear power and other large-scale and nonrenewable alternatives. Disagreements are limited to questions of which project, when, with what safety features, built and owned by whom. These energy projects are recognized, even by their advocates, as capital intensive, technically complex, and conducive to further centralization of economic and political decision-making. Since the energy resources exploited are nonrenewable, the cycle must continue.

The most important rule in getting onto a soft energy path is to use energy in ways that are suitable for the tasks at hand — in SEP jargon, matching energy quantity and quality to end-use requirements. Energy quantity is meaured by heat content in Btu's or joules; energy quality is generally measured by temperature and form. Then, and only then, should energy supply requirements be estimated. In most cases, the projects and programs will be less expensive than hard path proposals, less threatening environmentally, smaller in scale, and, though in some cases technically sophisticated, simpler to understand. Many will have the potential to be built, installed and controlled by groups within the community. In some cases, particularly during a transition period, abundant non-renewable energy forms, such as coal and natural gas will continued to be used; otherwise soft paths utilise renewable energy flows — sun, wind, water[5] and biomass. Nuclear energy is excluded because it epitomizes all the hard path problems and adds the threat of nuclear proliferation.

Soft energy studies have advanced greatly in sophistication since their inception several years ago. To anticipate what will follow, the major lessons learned to date are: (1) concentrate efforts on the demand for energy and the quality of energy required; (2) model shifts in transport (air to rail; car to bus) and materials shifts in industry (more recycling; designs that economize on concrete) can substantially reduce major gaps in fluid fuels that remain after allowance for improved technology; (3) a variety of solar technologies will enable more complete thermodynamic matching of end-use to source; and (4) even "high" forecasts of economic and population growth can be utilized to demonstrate the viability of a renewable energy society.

Institutional and Policy Aspects

Idealy, an SEP study will examine and evaluate each concept from many perspectives - economic, social, political and institutional. However, since most SEP analysts have far fewer resources than those available to hard path analysts, a more limited study is usually necessary. Consequently, economic feasibility and the attainment of a few specific goals, such as employment, that rank high in political debates tend to be highlighted in SEP studies. This means the exclusion of such concepts as social diversity, ecological harmony and centralization (all of which are also eschewed by most hard path studies). Because the impact of such concepts will generally increase the attractiveness of a shift to a soft path, their omission is a major concession. In short, engineering and economics, not ecology and political science, provide the most immediate (though not ultimately the most important) support for soft energy paths over hard ones.

Working Backwards

The final step of a soft energy path involves "working backwards" to the present to see which technologies have to be deployed, and when, in order to arrive at that soft energy future. In this process, the implications of one or more soft energy futures (or, more accurately, of the policies that would lead towards them) can be compared with those of existing energy policies. In so doing, it often becomes apparent that the "business as usual" base case is not at all likely. By the same token, the transition problems involved in switching from one energy path to another (as with particular groups of workers who may be displaced) can be brought to the fore in order that "safety nets" can be incorporated.

2

Basic Principles Of a Soft Energy Study

Key concepts utilized in developing SEP studies will be explained in this chapter. Emphasis is placed upon conservation techniques, efficiencies and economic costs rather than on scale, decentralization and the varying political and environmental impacts of different energy technologies.

Defining an Organizing Theme

The organizing theme of a study is the base from which assumptions are derived, data arranged, methods chosen and analysis conducted. This is just as true of hard as of soft path studies. Typical forecasting exercises contain within them the very assumptions that are necessary to "prove" that a hard energy path is either essential or likely. Indeed, some of these "neutral" forecasts are better seen as explicit attempts to create a milieu with which a specific policy result will obtain.[6]

Common approaches to developing energy scenarios often lead to arguments about details rather than about broad directions. It is more useful to policy makers if energy paths can be defined in terms of policy options which incorporate the goals that governments normally think of. Therefore, it is important that soft energy paths, however well determined in their **quantitative** dimensions, be framed primarily by the **qualitative** socio-political structure of the energy system that they represent. In this way the conclusions will flow not from a few arbitrarily assumed numbers and growth rates, but from the goals and criteria inherent in one view (or a set of views) of what a future society might or should be. Thus, the choice of an organizing theme for a soft energy study is paramount and so is the necessity for explaining clearly the ideas underlying that theme.

Some of the more common themes utilized in energy studies are the following:

(i) **Extrapolating the past into the future**: This approach freezes the status quo; the future is the past writ larger. Many such studies become enmeshed in the complexities of calculating the various parameters that apparently measure past energy behaviour in order to make detailed projections that purport to esimate future behaviour. Most past energy studies were of this type though complex estimating equations may mask their theoretical naivety. An example is the 1973 Federal report, **An Energy Policy for Canada: Phase I.**

(ii) **Extension of existing relationships**: With this theme economic and policy variables are given explicit roles in determining results. Energy price becomes an independent variable. Hence, such studies tend to provide a richer explanatory and descriptive perspective than those of type (i). A few changes in specific relationships can be accepted but not structural changes. An example is the 1976 Federal report, **An Energy Strategy for Canada.**

(iii) **What if scenarios**: Whereas the previous two themes attempt projections based on the past, a third introduces a "What If?" question. What if Canada made a national commitment to reduce energy use? What if Canada decided to maximize energy exports? Such studies are explicitly argumentative and normative; explanation and scenarios replace projections. The problem with this approach is that it can become wishful thinking. That is, if the first two approaches suffer from being too closely tied to the past, this one can suffer from being too independent of that past.

(iv) **Maximum efficiency**: Another organizing theme focuses on the efficiency of energy production and use. Conventional economic and demographic projections are accepted but goods and services are provided as efficiently as possible, with efficiency generally defined in economic terms (maximum payoff in dollars) but in some cases in physical terms (minimum energy consumption). The problem with the former is that what pays off is determined by historical investments and institutions, neither of which is sacred. The problem with the latter is that it ignores the dollar and time costs of achieving greater physical efficiency. Still, some notions of efficiency infuse most energy studies, and it is useful to see where a trend to greater efficiency will lead.

(v) **Energy targets**: In this approach, one energy target (or possibly more than one) is postulated as a social goal for some future year. Then researchers can work backwards (backcast) to ascertain what is required (and when) to meet this target. The range of policies to attain the specific target is broad and can include agricultural, housing, transportation and environmental policies. This approach can be instructive but it emphasizes levels of energy use rather than of the activity that the energy is intended to serve.

These five themes are pure types. Most real studies incorporate elements of two or more. For example, it is common in soft energy studies to adopt rather simplistic projections of population and income but more sophisticated efficiency concepts. It is feasible to do so and also allow for more renewable energy because SEP studies tend to look further into the future than do typical hard energy path studies. Another combined approach is to splice relevant observations of existing social trends (eg. the trend to smaller family units) into accepted political and economic forecasts.

It is of course possible to go further and drop official forecasts in favour of major shifts in social values or economic structure. In this case, energy policy still remains on centre stage for the analyst, but it has to be developed within the context of a larger set of social and institutional changes, which must themselves be forecast or postulated. The conserver society theme has provided such an alternative perspective for many soft path analysts in Canada.[7] This theme is particularly relevant for SEP studies because it is based on, among other things, lower rates of material throughout in society. Similarly, in developing regions it will generally be necessary to postulate some alternative scenario for the future since the whole goal of development is to break with the economic and social patterns of the past.

End-Use Analysis

Regardless of organizing theme, it is essential that analysis begin at the point of end-use — the way in which energy is directly consumed to heat homes and office, fuel automobiles and trucks, power appliances and heat boilers. This is often referred to as secondary energy in contrast to primary energy which includes also the extraction, transportation, refining and conversion losses.[8] Primary energy consumption has been growing relative to secondary, mainly because of increasing electrification and the shift to non-conventional fossil fuels.

End-use data should be obtained in the most complete form possible. SEP researchers categorize by consumption sector and by temperature or form. Sectoral breakdowns follow the usual divisions of Statistics Canada — industrial, commercial, transportation and residential. Note that the definition of "industrial" as used in energy data differs from that used in economic data. In the latter "industry" includes all transactions in which goods and services are produced and sold through market transactions; as such it includes most commercial and transportation activities. In energy statistics the term "industry" includes primary industry (except agriculture, which is typically included in data for residential), manufacturing and construction. The energy supply industry is generally treated as a separate sector. Petrochemicals may be treated as part of manufacturing or of energy supply.

Energy quality distinctions are usually based on the form in which energy is supplied: heat, liquids and electricity, with heat (by far the predominant form) being broken down into three or more temperature ranges. Together with the consuming sectors, it is generally possible to develop a matrix, along the lines of Table 2.1, showing the quantity of each form of energy used in each sector. **Remember to specify date and place. And to use units consistently — preferably metric (joules).** (It may be better to stick with the common units in your area and then convert everything at one time than to risk the chance of errors by converting some data as you go along. See Appendix IV for conversion factors).

An advance in soft energy studies over most others is that the actual quantity of energy supplied in liquid or electrical form is distinguished from what really had to be provided in these forms (which are almost always more expensive in dollar, energy and environmental terms). To be sure, what must "necessarily"

Table 2.1
Consumption

Secondary Energy Consumption in ________________
for the year 19____ by quality and consuming sector.
(10^{xx} joules)

Energy Form	Resid.	Comm.	Indus.	Trans.	Total
Heat (°C.)					
100°					
101° - 315°					
316° - 1,000°					
1,000°					
Liquids					
Electrical					
Total					

(1 kW.h = 3,600 kilojoules)

be supplied in liquid or electrical form is in part a matter of choice (there are gas lights, electrical autos etc.), but the concept is still very useful. SEP researchers usually define necessary liquid by the working assumption that all transport currently fueled by liquids continues with that fuel source. The working assumption for necessary electric includes lighting, electronics, electro-processing, motors etc. and also assumes that end-uses that currently depend on electricity will continue their dependence. Both assumptions can of course be altered in the study. For example, mainline railroads in Canada could be electrified. On the other hand, a shift out of electric water heating or cooking in many parts of Canada seems unlikely. (One way to handle this problem is to distinguish "convenient" from "necessary" electrical demand.)

Unfortunately, thus far, governments have had little interest in how energy was used, so data for end-use breakdowns are typically scattered, incomplete or just non available. Also, many data are not available in terms of physical units of consumption, but only in terms of monetary expenditures. (After all, **someone** collected the bills.) In periods when prices are constant these can be converted to physical terms fairly easily, but in other cases great caution must be exercised. (See Appendix V for price deflators.)

Forecasting and Backcasting

Once the analyst has catalogued energy end-uses by sector and quality, the question of future growth, if any, of these sectors and end-uses is faced. Most SEP studies begin with official forecasts of new housing starts and mixes, population growth, household formation, migration and industrial growth. Some shifts in preferences or institutions, and saturation rates for consumer goods, can be included but must be made explicit.

Of course, official energy forecasts are **not** accepted. Instead, energy demand is analyzed to determine reductions possible through conservation, and supply is analyzed to determine the potential of renewable and transitional fuels.

A major difficulty faced by all approaches, and indeed by all energy forecasts, is the difficulty of estimating end-use scale and efficiency characteristics for any long period. If one considers the end-use changes between 1900 and 1950 (from horse to motor car), and then the possible changes between 1975 and 2025 (from motor car to videophone?), the problem is apparent. Nonetheless, the organizing theme will guide the researcher to some broad profile of end-uses.

At this stage the energy requirements to meet these end-uses is analyzed backwards from the end-point to the present. This backcasting can show how an energy-efficient building code enacted in, say, 1985 will affect residential energy consumption by 2000, or how many square metres of solar panel production are needed to meet a target of 100% solar heated office buildings in 2025. The procedure is typically iterative — repeated as one intensifies or relaxes assumptions about energy efficiency and renewable supplies over time.

A sample list of policy measures used in one backcasting exercise is shown in Table 2.2.

A further difficulty in energy studies is that feedback effects between energy use and the economy are ignored. They are also ignored in all hard path studies (if they are not simply assumed). Note, however, that such feedback cannot be ignored in those regions or provinces where energy **production** makes up a significant part of the economic activity. There the relationships between total output (not necessarily total consumption) and the economy will have to be considered.

Special Aspects of SEP Studies

Energy Conservation: Energy conservation is the application of any technology, regulation, policy or other measure to effect a reduction in quantity of energy consumption. SEP studies usually differentiate between technical fix and lifestyle measures. Technical fix measures are those which do not substantially change the nature of the service: increased attic insulation is a perfect example. Lifestyle measures are those where the behaviour of

Table 2.2
Examples of Policy Measures

Demand Management By Sector	
Residential	- all new homes insulated to reduce energy use for heating to 15 Gj/yr. - Existing homes improved in efficiency by 50%. - 40% increase of all electrical appliances efficiency. - 60% increase in efficiency of all hot water heating systems.
Commercial	- good housekeeping measures, implemented at the beginning of the period, cut energy use by 25% in existing buildings (per square metre of floor space). - after 1990, no heating in new buildings and electrical use cut by 50% per square metre.
Industrial	- housekeeping and minor process change yield overall 25% cut in energy use per unit of output by 1990. - Industry — specific changes; e.g., pulp and paper industry become energy self-sufficient from 1980 on and recycling plus changes in process and construction practices hold the absolute demand for high-temperature energy constant.
Transportation	- vehicles: smaller cars, housekeeping, slower speed operations, and shift to diesel motors doubles vehicle efficiency by 1990 and triples it by 2025; gradual shift to urban auto fleet to methanol and modal shift out of autos for urban community. - Rail and Transit Vehicles: gain of 25% in efficiency by 1990 through increased load factors, regenerative braking, and innovative trolley propulsion systems.
Supply Policy Measures By Sector	
Liquid Renewables	- crop wastes potential developed 100%. - biomass plantations begun. - forest biomass waste potential developed 100%.
Oil	- continued utilization of established reserves. - increase of tar sands production; no heavy oils. - gradual reduction of imports. - shift to petrochemicals industry from oil to gas for feedstock.
Natural Gas	- continued utilization of established and new reserves for heating, cooking, etc. - extension of service to Québec and Maritimes from West and/or Arctic. - some industrial substitution of gas for oil in East.
Electricity	- Coal: consumption reduced by almost 50% of 1974 level by 2000. - Co-generation: extensive development for new demands (e.g. 3,000 megawatts in Ontario by 1990). - Hydro: completion of facilities already planned but no new large-scale hydro. - Wind: used in remote areas to yield marginal substitution against diesel oil. - Nuclear: no additions beyond plants already in construction. - Wood, Garbage, etc.: a few plants in special areas. - Active Solar: none

individuals changes or the service provided to them differs. Shifting of commuting patterns from autos to public transit is a mild example; accepting lower monetary incomes, a more impressive one.

Technical fixes and lifestyle measures can be voluntary or mandated. The recycling of pop cans would be a voluntary measure; a government ban on pop cans would be a legal measure. SEP studies should specify not only the type of measure but also its means of implementation.

There exist many gray areas between technical fix and lifestyle changes. Consider government regulations which require a switch in production to smaller cars and tax measures which induce the public to buy smaller cars. The mode and distance of travel may not alter, but the style of travel will.

Transitional Technologies: Transitional technologies in Canada are those that:

- indirectly conserve fuel by efficiently using existing fuels;
- use coal resources in relatively clean, efficient, variably scaled plants;
- utilize material otherwise deemed waste (municipal wastes, thermal effluent from power plants);
- efficiently utilize natural gas from southern Canada and perhaps the Arctic.

With appropriate planning and design, transitional technologies will ease supply pressures on existing sources and release capital for renewable technologies. For example, fluidized Bed Systems are a technical development that will combust almost any fuel at a variety of scales of operation with greater efficiency and lower effluents (except CO_2) than conventional systems. They show great promise for the combustion of coal and wastes.

Transition fuels can be combined with improved consumption technology. Industry utilizes a great deal of fossil fuels to produce steam. Such steam can also be used for co-generation of electricity. The waste heat from this process can then form part of process heat. In turn, waste process heat can be captured to heat buildings. Thus the energy quality of the fossil fuel is cascaded from high-temperature, high-pressure steam to low-temperature, low-pressure space heating. Cogeneration itself is an enduring rather than a transitional technology because it can be adapted to any fuel and because it improves efficiency.

Substantive treatment of transitional technologies is lacking in many SEP studies. Usually they are noted as helpful, or bits and pieces of these measures are mixed with conservation or renewable energy sectors. Since the technologies have a wide range of application across energy qualities and consumption sectors, they deserve as much investigation as conserving and renewable technologies.

Complicating all transition technologies are local political and economic considerations. For example, most provinces in Canada have an electrical surplus, so it is worth considering how this exciting capacity can be used without creating long-term tendencies in the wrong direction. Similarly, there seems to be a Federal policy developing to get natural gas to the Maritimes. Assuming such a policy, how could gas systems be designed so as to lead most efficiently to a renewable energy future (e.g., by adopting it to the solar mini-utility approach)? In the same way, local employment conditions may have to be considered, as well as balance of payment considerations. The latter do not apply merely to nations, but also to provinces. For example, part of Prince Edward Island's energy problem is predicated on the need to have high agricultural output, which in turn is used in part to pay for its energy imports. Québec's intention to become 41% electric by 1990 is predicated in large part on balance of payments considerations.

Energy in Trade: Most energy scenarios take account of direct trade in energy products — that is, imports and exports of oil, gas, coal and in some cases electricity — but few allow for indirect imports and exports of goods and services that embody energy. Implicitly, this amounts to an assumption that imports of energy in goods and services are about equal to exports. Such an assumption is unlikely to be true for countries or provinces which export primary products, which are of course the heavy industrial consumers of energy. Such countries are likely to be exporting a lot of energy sequestered in those products and thus tend to be less energy intensive than indicated by statistics on energy consumption. In contrast, countries that import primary products are likely to be concealing a part of their true energy intensity.

Canada is a good example of a country exporting energy in the form of primary products, principally metals and pulp and paper. A detailed input/output analysis of Canadian trade indicates that the energy content of Canadian exports in roughly 1×10^5 kilojoules per dollar, whereas the energy content of Canadian imports is about 0.75×10^5 kilojoules, or some 25% smaller.[9] (For the purpose of comparison, carbon steel typically embodies about 2×10^5 kilojoules of energy per dollar of product.) Given that about one quarter of Canada's GNP is derived from international trade, this represents a major adjustment that is necessary to any gross comparisons of energy efficiency. Of course, it also points to specific targets of importance for industrial energy conservation.

Renewable Energy Technologies: Demand or Supply?: It is common in official studies to categorize renewable energy sources in terms of their conservation potential — that is, as technologies that merely reduce the requirements for oil, gas and conventionally generated electricity. While this may be analytically convenient during a transition phase, it is not only conceptually wrong but also displaces our objective to seek an energy mix wherein renewable technologies supply most if not all the demands.

A few renewable technologies do not fall so neatly on the supply side of the ledger. Because passive solar energy is a combination of thorough insulation and clever design to capture solar heat, it is generally convenient to designate passive solar as a conservation measure.

Technology Choice and Timing: Determining which conservation, transition or renewable technology to choose, for what time period and at what rate of implementation is a matter for judgement guided by organizing theme. An energy efficiency approach might place greater emphasis on transitional technologies than a conserver society approach, or macro-hydro might be foregone in favour of equivalent amounts of micro-hydro in a decentralized scenario. Here is a point at which other considerations can be brought in. Many Canadians (not just whitewater canoeists!) are wondering how many more of our rivers we want dammed. It is only important that judgements be explicit and supported by argument and data.

Much the same sort of judgement applies to changing the form of energy required, especially via transitional or renewable technologies. Information must be provided on new technologies available for meeting specific end-use demands, and in some cases, it **may** be appropriate to override the principle of greater efficiency. A province with major forest resources might choose to use methanol as an industrial boiler fuel rather than import solar concentrators from Ontario. Thus the question of what is an appropriate quality match is framed by considerations that include not only thermodynamic analysis, but also scale, indigenous resources, relative economics and employment opportunities.

Appropriate Cost Analysis

Economic Efficiency: Economic criteria require that the most cost-effective technology be utilized. Cost effectiveness can be measured in many ways. The most precise measure is called discounted cash flow, but information is seldom adequate to permit such comparisons. A rough measure is given by payback period in which investment costs are compared with the number of years needed to recoup the same amount of money through energy savings. As a rule-of-thumb, the criterion for pay-off for business would be a three-year return of investment while for individuals and governments a five-year return was more appropriate. In making such calculations, do not forget that some investment costs are reduced by conservation measures; e.g. smaller furnace size. They will also be affected by new designs. For example, researchers in Saskatchewan have suggested that electrical backup for solar may save money because it avoids the need for any chimney (and thus cuts heat loss). If possible, calculations should be carried out on a life-cycle basis, that is, in terms of costs and benefits over the whole life of the investment rather than just its first cost.[10]

Symmetry of Analysis: The concept of symmetry is crucial in SEP studies, but continues to be misunderstood. Symmetry means two things. First, marginal costs for new soft systems should be compared with marginal (replacement) costs for hard ones, not average costs. Second, if environmental or safety costs are included for soft alternatives, they should be included for hard ones as well.

The most common mistake is to compare the cost of some, say, solar system, with the cost of supplying energy from existing fossil fuel or hydro capacity. This means that the (marginal) cost of new systems for solar are compared with the (average) cost from a mix of already-constructed hard facilities. No wonder the hard ones tend to look good! Everyone would like to produce at the capital cost of 10 or 20 years ago. The relevant comparison for the solar system is with oil produced from tar sand plants, or electricity produced from nuclear stations (not the first ones built, which were much cheaper than those of today). The situation is a little more complex for gas, given the apparently large supplies in southern Canada, which imply a constant cost situation for awhile. Nevertheless, ultimately the replacement for those supplies is Arctic gas, and the marginal cost becomes that of supply and delivery from the Arctic.

Whole System Costs: An attractive feature of soft energy technologies is the potential to supply energy according to scale of need — for home, office, industry — in many cases by on-site systems. In all cases, it is **delivered energy** that is relevant regardless of whether it is renewable or conventional. Therefore, whole system costs must be analyzed — not merely the cost of Arctic gas delivered to Toronto, but the actual cost to the Toronto household for the useful heat obtained from that gas versus useful heat obtained from a solar system.

Subsidies: Whenever possible, subsidies available to only one project or fuel type should be excluded from analysis. The main subsidies are available for oil, gas and nuclear production, but not for conservation or renewables. They include: (i) historic investments by government that support a high-energy infrastructure (interprovincial power lines and super-highways are but two of the many subsidies that favour existing energy industries); (ii) special tax provisions, mainly but not exclusively for the oil and gas industry[11]; (iii) price subsidies via "rolled in" pricing in which the high costs of new energy systems are averaged with the lower costs of existing ones so that energy appears (to the consumer) to be cheaper than it really is; (iv) special subsidies which aid particular industries (such as the federal support for nuclear R&D or provincial guarantee of hydro bonds); (v) general income tax provisions that permit expenditures on energy to be deducted in the year that they are incurred but require investments in saving energy or in solar systems to be capitalised.[12]

Set against these economic incentives are any that favour conservation and renewables. However, the subsidies for oil, natural gas and electricity projects are so pervasive and massive that there is little comparison. Studies in the United States indicate that, while the subsidy to the oil industry is largest in total volume, the subsidy to electricity appears to be the largest per unit of energy.[13] Within electricity the subsidy to nuclear is far and away the greatest. Unfortunately no comparable study exists for Canada, though back-of-the-envelope calculations suggest that federal incentives for oil and gas production amount to about $1 per gigajoules.

Externalities: Environmental monitoring and damage costs, safety and health costs, and social dislocations are pervasive in many energy developments, and they are usually paid in one way or another by the people living near or working on the project. Economic analysis of these "external" costs (external to the project managers) can be difficult. Indeed, dangers exist in attempting to evaluate effects which from many philosophical positions are unquantifiable. At best minimum dollar costs can be derived. In any event there is an enormous economic literature on dealing with externalities.

It is perhaps best for the SEP analyst to be content with providing examples that indicate the greater costs of hard approaches. In many cases the quantifiable data alone will be sufficient to prove the point. The addition of qualitative information will only make the conclusion stronger. In a few cases, as where a transitional scenario calls for more coal production, greater detail may prove necessary.

Conservatism: Conservatism in a SEP analysis comes from incorporating data that bias the analysis against soft paths. By listing and explaining such bias, SEP analysis obtains what Lovins terms "robustness." In effect the analyst is indicating that the SEP is feasible without all the additional factors that could strengthen the case. Common examples include: not accounting for the social or environmental costs of the hard path; ignoring lifestyle and value changes that could ease a soft path transition; accepting constant real prices for energy; neglecting changes to induce greater transit use or more recycling.

In short, SEP researchers must "bend over backwards" (which should come easily to analysts working backwards) to avoid overstating the case. We all know how the nuclear industry has contributed to its own problems by such overstatements.[14]

Implications

Shifting to soft energy paths will not solve all the problems of the world. It would be simplistic in the extreme, for example, to argue that the introduction of methane generators in poor communities will change social conditions. Furthermore, soft energy paths do not necessarily preclude tendencies to centralization, higher technology and larger scale.[15] What SEPs can do is provide an **opportunity** to work in the other direction, away from the above-mentioned tendencies. Hard paths, on the other hand, **require** centralization, higher technology and larger scale.

There are some technical implications that may or may not be dealt with in an SEP analysis. For example, satisfying peak demands and the need for storage or back-up systems are often raised as stumbling blocks to renewable technologies. These questions can be addressed either in the main body or in a technical appendix to the report. So can load management and marginal cost pricing.

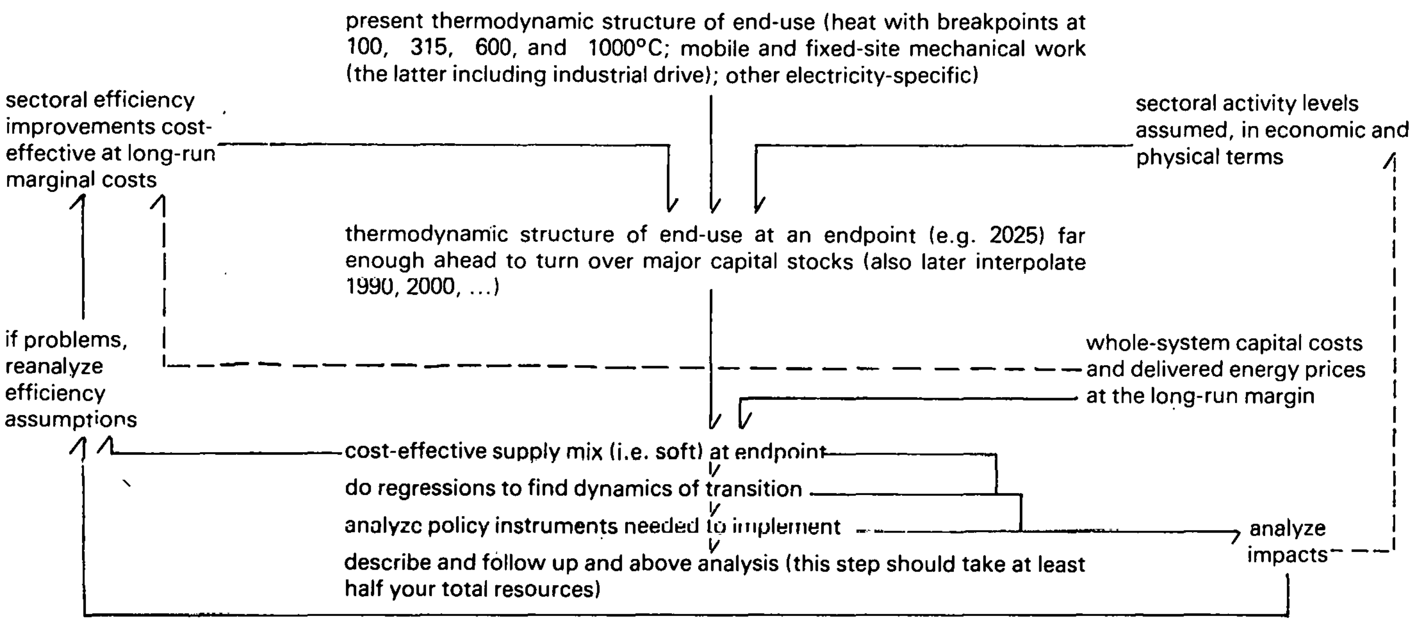
Most SEP studies result in shifts in the sectoral and energy quality end-use structure. Generally the industrial and transportation sectors become responsible for almost all energy consumption. In this situation an implication that can be addressed is internal consistency. Is the size and character of these sectors appropriate to the population and to energy consumption in other sectors? Without more study the question is unanswerable, but attention can be drawn to any apparent absurdities through a question such as: How much industrial output can consumers consume in 24 hours?

The question of regional exports and imports of energy will need consideration. Although most SEP studies begin by trying for self-sufficiency, this can be altered by resource and economic circumstances. It might be reasonable for Manitoba studies to assume methanol imports from northwestern Ontario, or for Alberta and British Columbia to assume coal exports eastwards. Needless to say, at some point imports and exports of energy should be brought into physical balance and implications for the monetary balance of payments noted.

Employment implications of SEPs require emphasis. Many studies indicate overall employment increases. Conservation and the production of renewable energy technologies yield more employment per dollar of investment than competing hard path technologies.[16] However, the employment may also be lower in pay and decentralized, which may mean non-union shops.

A further implication is the decline of some of our major industries, such as the automobile industry. With one of every seven workers connected somehow to the automobile, even stabilization of the industry is no small matter. The political and economic ramifications of industrial shifts to new products, new

Flow-chart



markets and innovative use of the plants and labour might be considered.

The above flowchart by Amory Lovins, along with the listing of methodological points following the chart, will help to synthesize the main arguments of this chapter, and lead to consideration of the details of an SEP study in Chapter 3.

Some methodological points (as developed at Peterborough workshop and later amended by Amory Lovins).

1. Start with end-use **thermodynamic** structure. Matching it will save money.
2. Work in secondary (end-use) energy and delivered physical functions; treat primary energy as derived.
3. Use multiple economic "conservatisms" and leave conventional "externalities" external to the extent that they are not already internalized by current policy.
4. Compare marginal with marginal and average with average.
5. Make all significant subsidies (on both sides) explicit.
6. Be rigorously symmetric in each criterion, economic or otherwise; apply it equally to hard and soft, supply and demand.
7. Use Systeme Internationale units (optional local units in parentheses).
8. Convert electricity to energy equivalent at enthalpic (heat) value, rather than introducing fictitious conversion losses. End-use efficiencies for each form of energy in each application should be counted separately at a latter stage of the calculation.
9. Make your assumptions about system boundary, trade, demography, etc. explicit and try to use figures reasonably consistent with those in common use.
10. Check for macroeconomic and sectoral internal consistency where possible — (Are you actually employing everyone? Do your job figures square with your cost figures? Do you project a reasonable balance of trade, or are you supporting massive export industries to pay for oil you're no longer importing?).
11. Check whether energy embodied in traded goods and services is significant, and if it is, treat it explicitly.
12. Check for statistical anomalies. For example, Denmark uses disproportionate amounts of jet fuel because overseas SAS flights tank up at Copenhagen; the bunker fuel used by the Norwegian merchant fleet is of the same order as total inland oil use.
13. Plan your review process from the beginning — as real participation and contribution, not just sending people **pro forma** reports of what you already did.

3

Undertaking A Study

This chapter elaborates on the concepts in Chapters 1 and 2 by outlining a manual to aid any reader wishing to undertake an SEP study. As the Peterborough workshop experience highlighted, there is no single best method. What follows is a guide, not a cookbook. Two references are used throughout: Ontario examples are taken from the Energy Probe study by Crow **et al**, and national examples from the Workgroup on Canadian Energy Policy study by Robinson **et al**.[17] Data have in most cases been converted from Btu's to joules.

Purpose/Audience

What is the purpose of the study? The question is crucial and by no means self-evident. Depending upon the answer the organizing principle of the study will vary, as will its depth and character. If the purpose is to demonstrate that official forecasts of GNP and other social indicators are readily attainable by soft energy paths, then a sector-by-sector approach focused on economic efficiency may fit; if the purpose is to compare various sociopolitical models, then comparative energy scenarios with emphasis on implications might be better. Closely linked is the question of the audience (s) being addressed. If the audience is broad, generalizations will be acceptable; if the audience is likely to be analytic, more depth is called for. **Because the approach emphasising economic efficiency of energy use is most widely practiced and was the workshop choice, this manual focuses on guidelines for this approach.**

What Scope and For How Long?

System boundaries for the study can vary from the neighborhood to the nation. One must balance the lack of data for smaller areas with the complexity as they grow larger — all within the context of available time, money and workforce. Given the regional variability of Canada, the most appropriate scale might vary from a region within a province (Southwestern Ontario) to a grouping of provinces (the Maritime Provinces).

Using boundaries that mesh with existing political or planning jurisdictions will make the study easier to read. To avoid being surprised in mid-study with the discovery that Statistics Canada does not record, say, oil consumption data for your region separately, review the energy data base **before** beginning a study.

A common time horizon for a soft energy study is 50 years. Most capital will turn over in that period, and it is long enough for institutional changes to take effect. However, even long-term government planning seldom goes beyond the year 2000. Under these circumstances many analysts have chosen 50- year end-points and intermediate check point (s). Insofar as possible, meshing those points with those of official agencies will aid comparison and understanding.

The Demand Options

End-Use Analysis

End-use analysis usually identifies energy by: (1) the sector of use (domestic, transportation, etc.); (2) specific function within the sector (heating, cooking, lighting); and (3) quality (low-temperature heat, liquid fuels), which establishes a framework for matching end-uses with suitable renewable supplies. Further subdivisions are made in heavily studied sectors. For example, transportation is categorized into its modes, divided into passenger and freight, urban and rural, as-needed and possible. Industrial consumption should be subdivided by industry.

Dividing sectors according to function — heating, cooking, lighting, etc. — is difficult. Few data exist on such categories, and interpolations and extrapolations are essential. One example of such data for Ontario is shown in Table 3.1.

Table 3.1
Distribution by Function

Distribution of Electrical Use in Ontario by Function, 1974

Function	Residential	Commercial	Industrial
Air Conditioning	1.0%	—	—
Clothes Drying	4.3	—	—
T.V.	5.2	—	—
Cooking	10 7	—	—
Refrigeration	13.8	—	—
Space Heating	20.2	5.8%	13.7%
Water Heating	29.8	5.8	13.7
Lighting	7.7	38.8	10.2
Motors	—	51.0	76.1
Others	7.3	4.4	—
TOTAL	100.0%	100.0%	100.0%

Source: Ontario Hydro information.

Table 3.2 shows the energy temperatures and forms needed for Ontario (**not those actually used since space-heating requires a temperature of 100°C maximum**). Information on temperature and forms actually used is not regularly collected, but some estimates have been prepared.[18]

Ideally, any end-use analysis should portray sectoral use and energy quality needs in a matrix format as shown in Table 3.3, which extends Table 2.1. Such a table, is of course, always rough because (i) energy data bases are often in disagreement as a result of differences in definition or data gathering problems; (ii) data are gathered for heat-type used (electricity for space-heating) rather than the thermodynamically appropriate quality of heat; (iii) sectors are not categorized according to functional use (the

Table 3.2
Temperatures and Qualities Required

Ontario Energy Temperatures and Qualities Required, (1974).

Task	Percentage
Heat 100°C	33%
100°C - 140°C	14%
140°C - 260°C	7%
260°C	5%
Necessary Electric	10%
Liquid Transport Fuels	28%

commercial sector may be a melange of apartment blocks, shopping malls, street lighting and small industry). The breakdown of industrial process heat as listed in Table 3.3 is not arbitrary but corresponds to actual temperature breaks as demonstrated by surveys of industry.

Before attempting to refine data by survey or other means, consider the time frame and scope of the study. **Adjust study precision to objectives and resources.**

Table 3.3
Schematic Format

Schematic format for Portraying Energy Consumption by Sector, Function and Quality.

Sector		Temperature/Quality
Residential	Space Heating	100°C
(sub-divisions	Water Heating	100°C
as appropriate)		
e.g. apartment,	Clothes Drying	
single family,	Air Conditioning	
etc.	Cooking	Mainly electrical
	Electric Lighting	
	Etc.	
Commercial	Space Heating/Cooling	100°C
(sub-divisions	Water Heating	100°C
as appropriate)	Cooking	100°C - 200°C
	Lighting/Refrigeration Motors	Electrical
Industrial	Space Heating/Cooling	100°C
(sub-divisions	Water Heating	100°C
as appropriate)	Process Heating	100°C
		100°C - 315°C
		316°C - 1000°C
		1000°C
	Lighting, Electro-processes and Motors	Electrical
Transportation	Passenger	
(sub-divisions	urban	liquid/electrical (?)
as appropriate)	rural	liquid/electrical (?)
e.g. auto,	Freight	
bus, rail,	urban	liquid
marine, etc.	rural	liquid/electrical (?)

Reducing Demand by Conservation

Having an end-use profile for as recent a year as possible, the next goal is to evaluate conservation potential and select conservation measures. To do this, it is first necessary to develop a forecast of the growth and attrition of end-uses. In addition, one needs criteria both for acceptance of existing and near-term conservation practices and for determining their rates of penetration. Each of these tasks will be sector and function specific, but will be related in a general way to the organizing theme of the study. Be modest in projecting advances in "state of the art" and decreases in the cost of conserving and renewable technologies. Much depends upon the price that is assumed for energy in the future. Similarly, one should adopt penetration rates that are modestly based and assume that new standards are only slowly implanted. The following sections suggest conservation measures to evaluate regardless of organizing theme; **they are in no way exhaustive.**

Residential Space and Water Heating: Space heating requirements for the residential sector normally receive the first attention of SEP analysts because this use is significant in total yet has a large conservation potential, and because the personal interest of the reader can establish a good beginning. This sector is broken down by housing type — single family detached, row housing, apartment, etc. — and future housing is distinguished from existing housing. For longer term analysis, some demolition rate will also have to be established. Much if not most of the statistical information can be obtained directly from government projections or inferred from trends in population, family formation and size, etc.

The list of conservation measures in Table 3.4 is generally accepted in order of decreasing cost-effectiveness for the **average single family Canadian home**. Some measures may not be cost-effective on some retrofit stock; other measures may reverse order on new stock. These and other measures can be appropriately combined according to type of house, period, and age of stock, with implementation and saturation rates, to yield a space heating demand. An obvious (but easy to miss) hazard is double counting the savings. Thus, if insulation measures reduce space heating to 75% of former value, then a heat pump will save 30% of that 75% and reduce the load to approximately 50% of former value. Be sure to allow for the different types of heating systems.

Table 3.4
Measures and Savings

Some Residential Conservation Measures and Average Savings on Space Heating

Measure	Average Saving
Weather Stripping & Caulking	5% - 10%
Roof Insulation R-20,30,40, etc.	10% - 25%
Floor & Basement Insulation R-15,20, etc.	10% - 15%
Storm Windows/Doors	5% - 10%
Heat Exchanger	10% - 15%
Heat Pumps	30%
Passive Solar	40% - 100%

Additional opportunities for reducing space heating requirements lie with district heating schemes. These can either be discussed at this point or left for a section on urban form. The latter is sometimes convenient because of the differences in decision making and in funding compared with individual housing.

Official forecasts of residential water requirements generally assume that hot water use per household will remain fixed at current levels. However, better projections can be made from data on average consumption per household and on heat source. Many measures can reduce the need for hot water, as shown in Table 3.5, which lists measures in rough order of cost-effectiveness. Once these measures are applied selectively with regard to fuel source and meshed consistently with the previously estimated stock and types of housing, future hot water consumption can be estimated by methods similar to those used for space heating.

At present water heating requirements are 15% to 20% of space heating requirements. However, if passive solar designs are widely incorporated into future housing, the proportion will be much higher (probably greater than half) because water heating forms an annual base load around which the small space heating demand varies by season. In addition, in urban settings large energy savings can be effected through district heating or preheating of hot water using thermal waste.

Table 3.5
Hot Water Conservation

Examples of Hot Water Heating Conservation Measures.

Types of Measure	Average Percentages Saved
Lowered Thermostats	5% - 20%
Tank Insulation	5% - 10%
Pipe Lagging	5% - 10%
Appliance Efficiency Upgrading	10% - 20%
Pre-Warming Tank	10% - 20%
Heat Exchangers	10% - 20%
Passive Solar Heating	?

Residential Electrical Demand: In an SEP study we are concerned only with necessary electrical demands. Consequently, for the residential sector the focus is on household appliances and lighting. (Any electrical space or water heating should have been previously considered.) Most electrical appliances are replaced within a 15 to 20 year period. This, coupled with the difficulties of modifying existing appliances, leads analysts to deal only with new models.

To analyze residential electrical demand, forecasts of appliance saturation per household (how many, of what type) can be combined with future appliance efficiencies[19] and existing attrition rates to yield electrical demand. For some uses, such as lighting, one can simply compare some overall efficiency improvement with expected growth. However, specific examples and details can provide startling examples. As Table 3.6 shows, results will vary from appliance to appliance. Table 3.7 shows one estimate of necessary residential electrical demand in Canada that included many, but not all, of the measures listed in Table 3.6.

Table 3.6
Appliance Conservation

Electrical Appliance Conservation Measures.

Appliance Type	Efficiency Measures	Average Savings
Stoves/Ranges	over circulation	20%
Refrigeration	improved insulation; small motors	50%
Television	solid state circuitry	80%
Air Conditioning	improved air flow efficiency	60%
Lighting	fluorescents; task lighting	30%

After completing the forecast for necessary electrical demand the stage is set to combine all elements to portray overall residential consumption. Typically end-point consumption is lower than that of today despite population and income growth but mid-point consumption may be a little higher.

Potential behavioural changes and their conservation impacts would likely increase the impact of technical changes, (beware of double counting) so their neglect is a conservative element. Observations can also be made about the impact of consumer education, better energy information, and the movement to a conserver society. Even so simple a measure as thermostat setbacks can result in large savings beyond technical fixes. At an

Table 3.7
Demand Analysis

An Example of SEP Analysis of Neccessary Electrical Demand in Residences in Canada

1974	1990	2005	2025
110	133	80	94 x 10^{15} joules

institutional level the potential impact of urban planning can be cited, as can that of site plans to harmonize with topography and micro-climate, infilling to reduce servicing and transportation costs, and more attached or cluster housing. It is more difficult to generalize such savings to the whole economy, but case studies show them to be significant.

The Commercial Sector: The commercial sector is a hodge podge of activities and structures. Most SEP analysts opt to shift some items to other sectors (e.g. new apartment blocks to the residential sector; mass transit to the transportation sector) and thereafter concentrate on the most significant item — large buildings. (The Federal Office of Energy Conservation estimates that large buildings account for 90% of commercial sector energy consumption.) This means that the bulk of energy consumption is for space heating and cooling and for lighting. Most of the remainder drives motors. For the rest of the sector, one can assume some standard efficiency gain, perhaps per dollar of consumption if physical data are not available.

Analytical difficulties with the commercial sector include forecasting general and specific growth (By how much will supermarkets grow compared with corner stores or co-ops?) and determining conservation potential among a wide range of structures and uses. Perhaps the only generalizations are that almost every building is grossly overlighted (or inefficiently lighted) and that there is enormous waste in building and food coolers (including freezers).

Many simplifying assumptions have to be used. They should be explicit and commonsensical. One researcher has utilized present and expected commercial employment with constant figures for floor space per employee to forecast future growth in overall commercial activity. When combined with existing energy consumption per employee and conservation potential, future estimates of demand can be obtained. Conservation potential is broken down into measures suitable for small structures and large structures, as shown by way of example in Table 3.8.

Table 3.8
Commercial Sector Conservation

Sample Conservation Measures for Heating and Cooling in the Commercial Sector

Period	Building Type	Stock	Measure	Savings
Near Term	Small	Old	Heat Exchangers and Insulation	30%
Near Term	Large	Old	Housekeeping measures and improved use of controls	25%
Long Term	Small	Old	Total revamping of heating systems; passive retrofits	50%
Long Term	Small	New	Insulation Standards Passive equal to residential	70%
Long Term	Large	Old	Computerization	30%
Long Term	Large	New	Passive solar; efficient design	80% - 90%

Specific examples illustrating these policy measures help to illustrate the feasibility of the overall conservation goal. For example, the Halton, Ontario, Board of Education lowered energy consumption 20% across 100 schools in two years by reduced illumination and temperature levels. The new Gulf office building in Calgary is expected to use less than 20% of the energy per square metre used by existing office structures. Table 3.9 shows the results of such measures as applied in one SEP study to future commercial sector energy consumption in Ontario. There were many conservative aspects in this analysis including the omission of heat pumps, no changes in communications technology (work at home instead of office), and, most importantly, zero attrition rate for existing, inefficient commercial structures.

Table 3.9
Index Numbers for Consumption

Index Numbers for Commercial Sector Energy Consumption in Ontario (1974 = 100).

1974	1993	2025
100	102	112

The commercial sector presents SEP researchers with many challenges, yet as one of the fastest growing areas of economic activity, it is worth spending time on. The method outlined here is only one alternative. Other methods include estimating necessary electric in a base year and then multiplying by the growth in some economic indicator (as a surrogate for the commercial sector) or projecting energy consumption per dollar of commercial output (taken from national income data).

The Industrial Sector: The industrial sector, like the commercial sector, is a potpourri of end-uses combined with an even wider range of energy qualities. It includes everything from machine shops to General Motors, from small fish plants to General Foods. In most SEP analyses the industrial sector becomes by far, the largest consumer of energy as other sectors improve their efficiency with time. It is also the one sector where high-temperature heat is used in large quantities. Hence one must spend time on the industrial sector, or at least on its major components (which typically include only 5 to 10 industries). The following industries account for 75% of industrial energy consumption in Canada and, overall, are five times as energy intensive (energy consumption per dollar of output) as the rest of Canadian industry:

Iron and steel	Food and beverage
Other primary metals	Chemicals and petrochemicals
Cement	Pulp and paper
Glass and ceramics	

Estimates of industrial energy use by quality in Ontario is shown in Table 3.10. Descriptions of energy use by function (heating, oxidation, steam etc.) would be useful but are rare. However, the use of higher temperature heat can generally be identified and separated into categories by function. Care will be needed to distinguish temperatures actually needed in a particular process from those now used. It can also be useful to consider inductrial energy needs by SIC categories.[20] Thus in the 315°C to 700°C range are found finished drying, pulp and paper, oil refining, petrochemicals, metal smelting and forming; above 700°C. are found the manufacture of glass, brick, cement, iron and steel, and metal refining.

Making forecasts of the profile of future industrial growth is perhaps the single most difficult task facing the SEP analyst. Some overall growth rate of x% will not help determine how much new plant will be built, since plant replacement/attrition rate will vary according to industry age, future output, changes in input composition, labour/capital ratios and so forth. Nor will it predict the decline or rise of specific industries. Given the resources usually available to SEP researchers, one alternative is to

Table 3.10
Consumption by Quality

Industrial Energy Consumption in Ontario 1974, by Quality.

Energy Quality	Percentage Consumed
Heat 100°C	4%
Heat 100°C - 140°C	38%
Heat 140°C - 260°C	20%
Heat 260°C	15%
Necessary Electric	15%
Liquid Fuels	5%

limit analysis to the aggregate level, and to assume that relative outputs among industries will remain unchanged over the time period — a weak but conservative assumption. However, it is preferable to allow expected changes, including those stemming from shifts in product mix — as to smaller autos which has implications mainly for the iron and steel industry. Above all, take account of the industrial strategy of the region being analyzed. Otherwise your analysis will lack realism and be dismissed by political people.

Conservation measures should be divided between old and new plant. It may be convenient to defer consideration of technologies such as cogeneration until the transitional technology section. Do not neglect the potential for housekeeping improvements. Plugging air leaks, maintaining optiumum air/fuel ratios, turning off lights and motors when not in use etc. can yield savings of 10% to 15%.

As in the commercial sector, illustrate the savings obtainable by example, preferably Canadian. The Standar Plant at Woodstock saved 2,000 bbls of oil and $20,000 by utilizing a heat-wheel. Dupont at Sarnia enacted a major steam trap maintenance program and saved 35,000 bbls of oil per year.

Special attention must be given to the heavy industrial users of energy. Without losing the emphasis on being modest in projecting technological change, it is worth looking at energy efficiency trends in recent plants and at what is projected in the technical journals. A study for a new ethylene plant in Sarnia indicates an energy efficiency improvement of 85% per unit of output over previous plants. Such information is, of course, only of use when linked to some specific plan of investment, but it is generally possible to find or make a reasonable projection for one industry or the few major industries in some region.

A further area to investigate when analyzing industrial energy consumption is the potential for recycling (or, even better, re-use) of materials. Not only does recycling reduce overall energy consumption but it also reduces consumption in the highest quality categories. For example, by increasing the proportion of cullet (broken glass) from 20% to 40%, the temperature of the glass furnace at one operation in Ontario was reduced from the usual 1500°C to 900°C with reduced stack emissions and prolonged furnace life. Production of aluminum from scrap can save 90% of the electrical requirements of new aluminum.

Transportation Sector: Most SEP analyses find that transportation demand is second only to that of industry. Furthermore, once improved auto efficiency is incorporated, the largest part of transportation demand turns out to lie with commercial passenger and freight transportation. The ways of coping with this will vary widely from region to region because of the diverse nature of geography and economy within Canada. It would be naive to assume that automobile and airplane travel will be reduced enormously, but this does not mean that the present structure of use need be maintained. In particular, decentralized rail lines adapted to local and regional needs deserve more consideration than they have received to date.

A typical end-use analysis focuses on transport mode (road, rail, air), activity variable (passenger-kilometres or tonne-kilometres), energy intensity minus load and energy intensity with load. Passengers and freight services must be separated and, if possible, urban and non-urban use.

As in other sectors, official estimates of future activities can be used as a basis for analyzing conservation potential. However, some SEP researchers allow for changes in living patterns and industrial structure that affect both activity and ownership. As for modal shifts within the sector, some researchers assume no shifts, so that mass transit, for example, has the same percentage of the market in 2025 as today. Others assume significant shifts, particularly to mass transit in commuting and from short haul air to rail or bus between cities. By and large, heavy freight already moves by rail or pipeline. However, medium and light shipments, particularly of food products, could also be shifted to rail, though trucking is usually required at either end.

So far as current knowledge goes, there appears to be less scope for technical fixes in the transportation sector than in other sectors — with the major exception of the automobile where improvements of 50% to 75% seem quite possible. Projections identify 20% to 30% savings with the next generation of trucks and airplanes but little beyond that. (One set of estimates for technical possibilities is shown in Table 3.11.) Further energy savings can be incorporated only if institutional opportunities can be defined. These range from minor changes in scheduling to avoid idling time to shifts in transportation practices and laws (which often maintain enefficiency).

Table 3.11
Transportation Conservation

Some Transportation Conservation Measures.

Sector	Measures	% Savings
Road Sector	Weight reductions, improvements in basic engine and transmission, radial tires, improvements in fuel combustion, and improved heavy trucks: 20% - 30% vehicle operation	50% +
Electric Transit	Gains in **propulsion** efficiencies and vehicle scheduling; regenerative braking	40%
Rail	LRC Trains, electrification of mainlines	20% - 30%
Aircraft	Design innovations	22% - 30%
Marine	—	Negligible

Technical and institutional measures (together with increased load-factors) should be adequate to avoid significant increases in future energy consumption for transportation in Canada, despite large increases in auto ownership, air travel and so on. This conclusion could turn out to be conservative. For example, a 40 mpg (7 /100 km) auto fleet after 1990 hardly does justice to automotive technology which today can build an 87 mpg (3.3 /100 km) Volkswagon and a 52 mpg (5.5 /100 km) diesel Mercedes. In addition, one can think of incentives to increase habits that range from likely (car and van pooling) to problematical (walking and bicycling). Even more striking are possibilities for substituting communications for passenger transportation and changing industrial structure to reduce freight transportation. Many materials move several times across the country as they are transformed from ore to metal to finished product or from agricultural product to foodstuff to food. However, such changes lead to increasing circles of impacts which require detailed evaluation if they are to be more than mentioned. And remember to **add** the increases of rail and mass transit energy consumption where necessary and to allow for any new investments required.

General Conclusions of the Conservation Action

A summary of conservation potential from the various sectors can be brought together as economy-wide totals. One SEP projection for Canada in 1990 is shown in Figure 3.1 in bar graph form in a comparison with official forecasts.

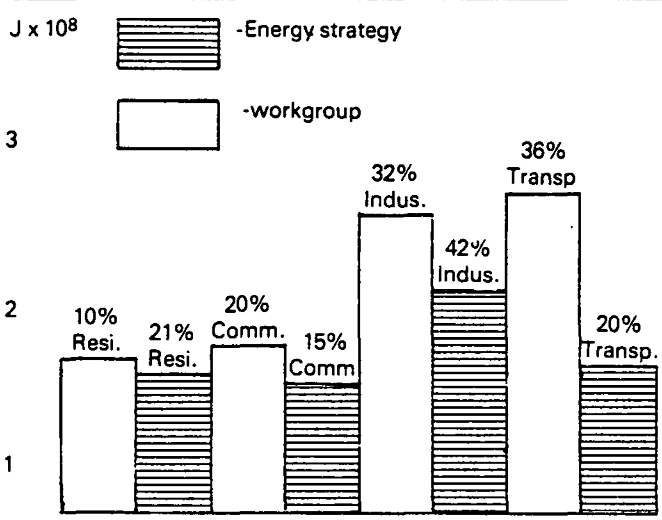


Figure 3.1. A Comparison of the high-price scenario from **An Energy Strategy for Canada** with the "B" scenario of the York University Workgroup on Energy Policy.

The Supply Options

Transitional Technologies

To a very considerable degree, time is not a policy constraint in developing a renewable energy future. Transitional technologies, selectively and forcefully implemented, will bridge the gap, and will demonstrate that our choices are not limited to being 100% solar energy by 2000 or going nuclear. Ideally transitional technologies should be analyzed with the same depth as conservation potential. Total energy systems, co-generation, fluidized bed combustion and natural gas all deserve close scrutiny. Remember that several of these systems assume that energy external to plant needs has a ready market in the commercial and residential sectors.

Industrial Cogeneration

With Canada's heavy reliance on primary industry, much of its energy intensive, attention must increasingly turn to the possibilities for energy cascading. Cogeneration (the simultaneous generation of electricity and useful thermal energy, generally as steam) is one specific application of cascading. The main advantages of cogeneration lie in improved energy efficiency, relatively low cost and economic efficiency at relatively small scale. Conventional electrical generation is only able to obtain first law efficiencies of about 35% whereas with cogeneration it is typical to achieve levels of 60% and, in ideal circumstances, 90%. According to one report, the efficiency of cogeneration in Ontario is 73% - 75%.[21]

The potential for cogeneration is of particular interest in those provinces of Canada that have a large forest industry. Such industries produce an enormous amount of "hog fuel" (bark, chips, sawdust, etc.) yet currently use an enormous amount of outside energy. While temperature range and the split between heat and electricity vary among pulping processes, and even among plants using the same process, the characterisitics of cogenerating systems permit each mill to match output to its own requirements. (Indeed, most pulp mills, particularly those using the sulphate process, should feed substantial quantities of excess electricity back into the grid.) Cogeneration can also be combined with district heating schemes in urban areas.

Building from European examples and experience, an SEP analyst can probably also assume that some industrial and commercial users will switch to fluidized beds from oil fired or inefficient coal-fired boilers. The same is also true for district heating. One method of calculating the potential of district heating is to assume a certain percentage of new housing starts from row or condominium sectors are thus served. Finally, do not neglect the possibilities for using natural gas, at least that from conventional areas.

Renewable Technologies

Fitting renewable supplies to mid- and end-point energy requirements is a three-part process. First, renewable energy technologies are matched to the energy quality required in the end uses. Assumptions regarding the 'state of the art' at present and in the future should be explicit. Second, potential output from these technologies is compared with project consumption for the appropriate time period. Third, backcasting will reveal what is necessary, when, and for which sectors. Excepting ultimate resource potential (which is fixed for both renewable and non-renewable resources, though not in the same way), the procedure for matching the magnitude and type of energy requirements will undoubtedly be iterative. It will often prove easier to cut back use of some form of energy than to build up supply. However, it is more difficult to provide general guidelines about procedures for matching energy supplies than for cutting energy demand.

A set of renewable energy technologies matched to quality of energy produced, and selected not only for their thermodynamic characteristics but also for economic feasibility, resource availability and least social disruption, might include the following: Low Temperature Heat: Solar - flat plate collectors and evacuated tube collectors, geothermal, district heating (many fuel sources) and wood. Medium and High Temperature Heat: Solar - selectively surfaced collectors, focusing collectors, tracking concentrators; also direct combustion of biomass, bio-gas, and methanol. Liquid Fuels: methanol and ethanol alcohols. Mechanical Work: micro hydro, solar heat engines and wind machines; also electric. Renewable electricity technologies include micro and macro hydro, wind machines, wave and tidal power, solar photovoltaics, wood and urban waste.

It is apparent that a diversity of renewable technologies already exists with many combinations possible to supply whatever energy needs are required. At this stage it is usual for researchers to **reduce** the number of technologies for analysis based on resource potential (e.g. crop wastes for Saskatchewan, methanol for British Columbia) and by limiting analysis to, say one standard solar heating system. One should as usual be conservative regarding the state of the art; thus, many analysts do not include photovoltaics as a source of electrical supply. In your report be sure to state how many renewable resources have been omitted to emphasize how great the potential really is.

In all cases the transition to renewable sources of energy should be gradual. For example, if the magnitude of demand for medium temperature heat is 1 quad in 1990, it would be logistically impossible, and probably wasteful, to assume that a solar industry could meet this requirement by 1990. If, however, the focus is 2025, the time does allow for a gradual curve of solar industrial growth. Do not forget that some renewable technologies, notably the introduction of methanol-based automobiles, require extensive infrastructure adjustments (in vehicles and pipelines) which take time and money. Moreover, allowance must be made for continued extraction of fossil fuels and conventional generation of electricity. This will balance the analysis and aid the audience to understand what a transition In energy sources can look like.

To complete the picture, provide energy supply and demand tables similar to those published by government for each midpoint and the endpoint, but with transition and renewable as well as conventional sources included. This will reveal areas where implementation possibilities are rapid and, conversely, where barriers and difficulties can be expected to slow implementation. Examples of previous rapid shifts in energy technology can be useful (e.g. the speedy introduction of natural gas heating in Britain and Holland).

Implementation

If generalization is difficult about study procedures for matching renewable technologies to end-use requirements for specific areas, it is impossible for implementation schemes. Pricing, financing, industrial development and government programs all need attention. A full SEP analysis will suggest ways to adjust both the incentives and disincentives in our system as appropriate. Perhaps the only area that has received a lot of attention is marginal cost pricing.[22] An overall implementation scheme has been developed for only one province.[23] And there has been practically no work on ways to ensure that renewable technologies serve to benefit those who need them most.

Handy Hints

(As developed at the Peterborough workshop and later amended by Amory Lovins)

1.
Put most of your analytic effort into demand, not supply.

2.
Identify the main demand terms and the problem supply terms **early**. This is worth a weekend of initial calculation to see where to concentrate your effort.

3.
Start writing early. This will make weak points more obvious while there is still time to give them the emphasis they deserve.

4.
Be modular and recursive. Modular means your chain of calculation is so built that you can unplug a number, refine it, plug it back in, and go on the next weakest number. Recursive means you keep looping back to refine assumptions and so solve problems you discovered later. People who think an SEP study is a predictable, cut and dried, linear process haven't tried to do one.

5.
Don't get hung up on a number. If you don't have it, put in a plausible guess (maybe all you need if it's an insignificant term) and continue. Come back to it later. Chances are pretty good you'll later find you don't need to know it very precisely anyway.

6.
Don't be overprecise, especially for small terms. It is the mark of educated people (said Aristotle) and a proof of their culture that in every subject they look for only so much precision as its nature permits or its solution requires.

7.
Keep assumptions explicit and clearly in mind. Write them down.

8.
Use bar charts from the beginning as a working tool to help you visualize end-use and supply structure. Don't wait to draw them until you're reporting your final results.

9.
Keep your calculations scrutable, documented, and transparent. Scrutable means a professional reader can reproduce your results from your stated data and method. Documented means your sources can be checked. Transparent means a lay reader can see the general outlines of how you did your calculations and thus understand what you did, even though he or she may not be able to do it.

10.
There is no such thing as accuracy in 2025. Just do the best you can.

11.
Keep thermodynamic structure of end-use foremost in your mind. (This means **inter alia** that most of your supply analysis should be for heat and liquids, not electricity — contrary to the usual emphasis in soft-path supply descriptions.)

12.
Have one person who **knows** the numbers, where they came from, and what the status is of each part of the analysis. (Two people are even better if they communicate.)

13.
Is it the strongest possible statement?

14.
Keep track of full bibliographic details of each source from the start so you don't have to go hunting for obscure references later.

15.
As you work, keep an eye out for analogies, precedents, and vivid examples.

16.
Beware of multiplying alternatives (alternative values for population, GNP growth, energy price, conservation measures selected, etc. etc.) lest you provide so many branch-points as to keep readers undecided indefinitely. Just choose the most internally consistent sets of assumptions you can, each reflecting a mind-set consistent with the scenario you're doing, and console yourself that since you've followed (9) above, interested readers will be able to alter your assumptions for themselves.

17.
Distinguish illustrative, unique and optimal paths. Just what are you claiming for your scenarios?

18.
Test sensitivities. State which assumptions are important to your results, which aren't, and why. Test resilience in the face of both calculable technical failures and incalculable kinds of surprises.

19.
Imbed local case-studies to lend concreteness and vividness. Try to pick the areas studied (a rural area, a town, a city) to be not only representative but also full of real quirks and sufficiently interested in your work to be a potential site for a field implementation test after you publish.

20.
Remember your audiences, especially those with perspectives different from your own, and the tentative structure of your product. You may want written reports for both lay and professional readers; videotapes; pamphlets for specialist audiences (architects, bankers, builders, farmers,....); comic books; filmstrips; TV shows; slideshows; all of these plus some more.

21.
Anticipate the political climate when you'll publish — probably able to appreciate lower energy projections than are fashionable when you start work.

22.
Anticipate major criticisms in your text (but don't be defensive).

23.
An SEP is not a panacea. People mustn't be surprised if it fails to solve all our social and political problems. Make clear that's not its intention.

24.
State clearly the boundary of your concern and of your analysis.

25.
Don't overestimate readers' ability to think of the long term. Many people think 1980 is long-term. Your results must bear on real, immediate decisions.

26.
The world doesn't stop at 2025. Discuss how, at that time, the energy system will be placed, what options will be open (or closed), what will still be happening.

27.
Remember that numbers aren't everything, and be sure your

readers know it too.

28.
If you include substantial population change, present your results as both total energy and energy per capita. Include, if possible, silly numbers like E/GNP ratios for people who think them meaningful.

29.
Specify what should be done next. What should your readers go out and do?

30.
Keep networking and pass on your experience.

Appendix I

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Appendix II

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N.b.: The following lists of references are by no means complete but merely identify resources that were used or referred to by the participants at the Peterborough workshop.

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Appendix IV

Basic Conversion Factors

1 short Ton	=	2,000 lbs. = 907.185 kgs.
1 long ton	=	2,240 lbs. = 1,016 kg. = 1.016 tonnes
1 tonne	=	1,000 kg. = .985 long ton = 2,205 lbs.
1 cubic metre	=	35.3 cubic feet
1 cubic foot	=	0.028 cubic metres***
1 metre	=	39.37 inches = 3.28 feet
1 tonne	=	300 U.S. gallons
1 tonne	=	7 barrels (bbls/day)
1 tonne/year	=	42 U.S. gallons = 35 Cdn. gallons
1 barrell	=	0.159 cubic metres***
1 Btu	=	1,054.8 joules
1 Btu	=	1.0550 x 10^{10} ergs
1 Btu	=	.252 kilogram-calories
1 toe*	=	10^7 kcal.
1 Mtoe**	=	10^{13} kcal. = 3.968 x 10^{13} Btu = 7 x 10^6 bbls.
25 Mtoe	=	1 quad.
1 year	=	8.766 hours = 525,960 minutes = 31,557,600 seconds.

* tonne of oil equivalent (a common OECD unit)
** million tonnes of oil equivalents (a common OECD unit)
*** These figures are approximate as exact numbers depend, in the case of natural gas, on temperature and pressure and, in the case of oil, on the "gravity" of the oil (which affects its thermal expansion).

Energy Content of Canadian Fuels

Fuel	Unit	Btu '000,000	Giga Joules
Cdn. bituminous	(short ton)	25.2	26.6
Lignite	(short ton)	13.2	13.9
Coke	(short ton)	24.8	26.2
Liquified			
Pet. Gases	(bbls of 35 Cdn. gal.)	4.095	4.32
Crude Oil	(bbls of 35 Cdn. gal.)	5.8	6.1
Motor Gas	(bbls of 35 Cdn. gal.)	5.222	5.51
Diesel	(bbls of 35 Cdn. gal.)	2.8275	6.15
Light Fuel Oil	(bbls of 35 Cdn. gal.)	5.8275	6.15
Heavy Fuel Oil	(bbls of 35 Cdn. gal.)	6.2874	6.63
Liquid Fuel			
Equivalents*	(bbls of 35 Cdn. gal.)	6.3	6.5
Aviation Gas	(bbls of 35 Cdn. gal.)	5.0505	5.33
Aviation Turbo Fuel	(bbls of 35 Cdn. gal.)	5.4145	5.71
Natural Gas	'000 cu. ft.	1.07/1.0	1.06
Electricity	'000 kwh	3.4120	3.6

* An average barrel of petroleum products (approx. = No. 6 fuel oil)

Some Useful but Approximate Conversions

Cost

Every $1 per bbl of crude oil means $0.16 per gigajoule
Every $1 per Mcf of natural gas means $1.00 per gigajoule
Every 1¢ per kW.h of electricity means $2.77 per gigajoule
(Therefore, $19 per bbl oil is about the same as $3 per Mcf gas and 1.1¢ kW.h electrivity).

Every $1,000 per kW of capacity will cost consumers 11 mils (1.1¢) per kW.h (N.B.: this assumes annual capital charges of $100 flat demand and plant operation at 100% of capacity; hence it is conservative.)

Every $1,000 per kilowatt of capacity is equivalent to $67,000 per barrel per day.

mills/kW.h x 1.61 = $/bbl

Energy

1 Quad equals	10^{15}	Btu (one quadrillion Btu)
	10^{15}	kilojoules*
	1	exajoule (10^{18} joules)*
	175	barrels of oil
	62	million short tons of coal
	1	trillion cubic feet of natural gas
	3	million megawatt-hours (thermal)

1 Quad is produced by 16 or 17 Pickering "A" nuclear stations (containing four 500 megawatt CANDU reactors (at 100% capacity factor).

1 joule = 1 watt-second
1 Btu will raise the temperature of 1 lb. of water by 1°F

Power (capacity or energy per unit of time)

1 Quad per year equals:
- 10^{15} Btu per year
- 33 million kilowatts (thermal)
- .5 million barrels of crude oil per day
- 175 million barrels of crude oil per year

1 barrel of oil per day equals:
- 67 kilowatts (thermal)
- 5.5 million Btu per day

1 million barrels of oil per day = 50 Mtoe/year = 2 quads/year.
1 horsepower (electric) = 0.746 kilowatts

Miscellaneous

1 mile per gallon equals 0.35 kilometres per litre.

1 gallon of fuel oil will heat 35 10-gallon bathtubs of water to 120°F. (provided there is no soap in the water).

6 aluminum beer cans require the energy equivalent of one gallon of gasoline to manufacture (there are 4,800 Btu per Bdà (basic daily ablution).)

100,000 Btu per square foot per year equals one million kilojoules (1 Gj) per square metre per year equals 29.3 kilowatt-hours per square foot per year equals 315 kilowatt-hours per square metre per year.

1 pound per square inch (psi) = 6.895 kilopascals.

Prefixes for Large Numbers

kilo = 10^3
mega = 10^6
giga = 10^9
tera = 10^{12}
peta = 10^{15}
exa = 10^{18}

(If they go still larger than 10^{18}, **conserve**!)

* When projecting to the year 2025, the 6% difference between kilojoules and Btu's can generally be ignored — but don't forget that it is **kilo**joules.

Appendix V

Purchasing Power of 1971 Consumer Dollar

Year	$	Year	$
1930	2.29	1948	1.78
1935	2.87	1949	1.72
1940	2.62	1950	1.68
1945	2.30	1951	1.52
1946	2.22	1952	1.48
1947	2.03	1953	1.49
		1954	1.48

1955	1.48	1966	1.20
1956	1.46	1967	1.16
1957	1.41	1968	1.11
1958	1.38	1969	1.06
1959	1.36	1970	1.03
1960	1.35	1971	1.00
1961	1.33	1972	.95
1962	1.32	1973	.89
1963	1.30	1974	.80
1964	1.27	1975	.72
1965	1.24	1976	.67

Source: Statistics Canada, Consumer Price Index Catalogue No. 62-010.

Note: For many purposes in SEP analysis it is preferable to use other indices, such as the deflator for producer goods.

Footnotes

1.
The Yukon and Northwest Territories have unique climatic, settlement and resource circumstances. However, preliminary work by environmental groups suggests that soft paths are no less appropriate in the mid-North and the far-North, than in the South.

2.
MacKenzie Valley Pipeline Inquiry, **Northern Frontier: Northern Homeland** (Ottawa: 1977), 2 volumes.

3.
Royal Commission on Electric Power Planning, **A Race Against Time**, Interim Report on Nuclear Power in Ontario (Toronto: Queen's Printer for Ontario, 1978).

4.
Careful study of Lovins' book, **Soft Energy Paths: Toward a Durable Peace** (Cambridge, Mass., U.S.A.: Ballinger/F.O.E., 1978), is essential to anyone undertaking soft energy analysis.

5.
In a sense even big hydro projects are nonrenewable. The sites get used up and then, if demand keeps growing, you must move onto a more distant or less advantageous site for the next block of hydropower. Also, rivers have alternative uses that are precluded when dams are built.

6.
Some of the deficiencies of existing forecasting approaches are described in the following:
John Robinson, Wishful Thinking in Forecasts, **The Probe Post** (Jan.-Feb. 1979).
David Brooks, Forecasting the Past, **Report on Confederation** (Feb. 1979).

7.
Science Council of Canada, **Canada as a Conserver Society**, report no. 27 (Ottawa: 1976).

8.
Definitions of primary and secondary energy vary from one source to another. Soft path analysts need to be aware of the specific, statistical definitions used. In general terms primary energy is energy as it is first produced and measured at the wellhead, the mine or the hydro plant. Secondary energy is energy as it is purchased by consumers. It is always less than primary energy for three reasons. (1) because of losses in processing and transportation; (2) because some primary energy is used to make petrochemicals and other non-energy products; and (3) because roughly three units of fossil fuel energy must be consumed to obtain one unit of thermally-generated electricity....Ideally, one would work with what could be called "tertiary" energy — the energy that actually does work for us. Tertiary energy would be still smaller than secondary, because of inefficiencies in the consuming system, and would vary with the form in which the energy is supplied. However, except in a few cases, such as space heating, data are not available to permit analyses in terms of tertiary energy.

9.
Kirk Hamilton, **External Trade and Energy Consumption**, Structural Analysis Division, Statistics Canada (Ottawa: 1977)

10.
Marc Ross and Robert Williams, **Energy and Economic Growth**, A Study for the Subcommittee on Energy of the Joint Economic Committee, U.S. Congress, 1977, pp. 55-56.

11.
These can be enormous in some cases, as for drilling in the Arctic, where a 200% return of expenses is provided. Even conventional oil and gas drilling is done with 5-cent dollars; that is, taxpayers contribute about 95% of those "big, tough, expensive" jobs shown in the ads. See **The Calgary Herald** (22 Aug. 1979).

12.
The effect of this otherwise appropriate accounting practice is significant. See, for example, R.H. Bezdeck **et al**, Economic Feasibility of Solar Water and Space Heating, **Science**, volume 203 (March 23, 1979), especially Table 5.

13.
Soft Energy Notes, Vol. 1 (Oct. 1978), pp. 79-80.

14.
Every proponent of soft paths should read, perhaps every six months, the late David Comey's speech: "Tell the Truth," reprinted in **Not Man Apart** (Mid-March 1979).

15.
Mons Lonroth **et al**, **Energy in Transition** (Stockholm: Secretariat for Future Studies, 1977), p. 119.

16.
David B. Brooks, **Economic Impact of Low Energy Growth in Canada: An Initial Analysis**, Economic Council of Canada, Discussion Paper 126 (Ottawa: 1978). Peter A. Victor, George Hathaway and Jack Lubek, **Solar Heating and Employment in Canada**, Dept. of Energy, Mines and Resources report ER-79-1 (Ottawa: 1978). Christopher Conway and David B. Brooks, **Energy and Employment Alternatives** (Energy Probe: Toronto, June 1978).

17.
Full citations in Appendix III.

18.
For a Canadian report, see: Puttagunta, V.R., **Temperature Distribution of the Energy Consumed as Heat in Canada**, Atomic Energy of Canada Ltd., publication AECL-5235 (Pinawa, Man.: 1975)

19.
Canadian Federal Standards have been proposed in a background paper of 1976, but none have been implemented.

20.
Standard Industrial Classification (SIC): a numerical code of up to four digits that represents a classified list of all Canadian Industries.

21.
Leighton and Kidd, Ltd., **Report on Industrial By-Product Power**, Report to the Royal Commission on Electric Power Planning (Toronto: 1977).

22.
National Anti-Poverty Organization, **Stop the Ontario Hydro Pricing Shell Game**, Final Argument before the Ontario Energy Board Hearing on Electricity Costing and Pricing (Ottawa: Public Interest Advocacy Centre, 1979).

23.
Christopher Conway, **et al**, **Energy Planning in a Conserver Society: Implementation Strategies**, Energy Probe Report to the Ontario Royal Commission on Electric Power Planning (Toronto: 1979).

Document Control Page	1. SERI Report No. RR-744-451	2. NTIS Accession No.	3. Recipient's Accession No.

4. Title and Subtitle Decentralized Energy Studies: Compendium of International Studies and Research	5. Publication Date March 1980 6.
7. Author(s) Cissy Wallace	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	10. Project/Task/Work Unit No. 5629.99 11. Contract (C) or Grant (G) No. (C) (G)
12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered Research Report 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This compendium was prepared by the International Project for Soft Energy Paths as a part of the Decentralized Energy Studies task at the Solar Energy Research Institute. The purpose of the compendium is to provide information about research activities in decentralized energy systems to researchers, government officials, and interested citizens. The compendium lists and briefly describes a number of studies in other industrialized nations that involve decentralized energy systems. A contact person is given for each of the activities listed so that interested readers can obtain more information.

17. Document Analysis

a. Descriptors Decentralized Energy Systems; Surveys; Canada; Denmark; Federal Republic of Germany; France; The Netherlands; Israel; Italy; Japan; New Zealand; Sweden; United Kingdom

b. Identifiers/Open-Ended Terms

c. UC Categories

58e

18. Availability Statement National Technical Information Service U. S. Department of Commerce 5285 Port Royal Road Springfield, Virginia 22161	19. No. of Pages 70 20. Price $5.25

Form No. 8200-13 (6-79)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980—677-175/220