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ENERGY CONSERVATION TECHNOLOGY DEVELOPMENT

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REPUBLIC OF KOREA

Technical report: Assistance to Korean Institute of Energy and Resources (KIER) in technology management*

Prepared for the Government of the Republic of Korea
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of D. Hill, technology management expert

Backstopping officer: M. Farah,
Industrial Management and Rehabilitation Branch

United Nations Industrial Development Organization
Vienna

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* This document has not been edited.

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CONTENTS

On Friday, 15 July 1988, I reported to your office in the company of Dr. Chang-Sup Oh, Korea Institute of Energy & Resources, to begin my assignment to KIER as a Technology Management Expert-I. On your instructions, I am submitting this report of my activities in this post.

15 July - Reported in the afternoon to Dr. Shin Heesung, Director, Energy Conservation Analysis Division, KIER. After introductions, he requested that I draw up a work plan for his approval, specifically to plan development of MARKAL Model of Korea.

16 July (half day) - Reviewed flow charts of energy flow in Korea. Overall Reference Energy System (R.E.S.) appears complete for 1986 but has no English labels. Detailed flow charts show sources & sinks of energy flows without quantities. Example of U.S. energy data for U.S. MARKAL Model, previously given to Dr. Shin on floppy disc for personal computer, cannot be printed out. I suggested that Symphony software was needed because that was used in coding the data.

18 July - Dr. Shin approved a 7-point work plan for my visit (Appendix A). Discussed with Dr. Shin the additional software needs for putting up the MARKAL Model which depends upon the computer to be used. As the first step toward a Gantt chart of MARKAL Development, I prepared a draft "Development of Korea MARKAL Model Logic Flow" for review by Dr. Shin (Appendix B). The example of U.S. Energy Data for the U.S. MARKAL Model ("The Blue Book") was successfully displayed on the computer monitor by Mr. Jang-Woo Lee of the KIER Staff but could not be printed out because of a computer problem.

19 July - Dr. Shin reviewed the draft "Logic Flow" and approved it with revisions. Completed "Procedure for Developing MARKAL Model of Korea" based on "Logic Flow" (Appendix C). Dr. Chi-Hyuck Jun, Pohang Institute of Science & Technology, consultant to KIER, arrived to participate in the work.

20 July - I prepared a preliminary Gantt chart for a 2-phase, 2-year plan for developing the MARKAL Model of Korea and circulated copies of it together with the "Procedure." Dr. Shin asked for more detail in the Gantt chart. Prepared transparencies to be

used in presenting seminar on "Choosing Among Future Energy Technologies."

21 July - Completed preparation of transparencies for seminar. Begin preparation of "Check List for Technology Data Entries in MARKAL Dict./Data" to provide information on coding technology data for input to MARKAL. "Blue Book" was successfully printed out by Mr. Lee.

22 July - Completed the "Check List" (Appendix D). Reviewed preliminary Gantt chart with Dr. Oh, Mr. Lee, and Mr. Kim Kwun Il for revision in timing & duration of tasks. Revised the Gantt chart to version No. 2 (Appendix E). Answered questions on the content of the "Blue Book." Explained the "Check List."

23 July (half day) - In response to Dr. Shin's request for more detail in the Gantt chart, I prepared a list of detailed tasks for Phase 1. Based on the this list, I prepared a draft job description for work to be accomplished during a planned visit by Dr. Oh and Mr. Lee to Brookhaven National Laboratory, U.S.A., at Dr. Shin's request. I attended a luncheon meeting with Dr. Soo-Hyun Choi, Director, Energy Conservation Technology Center, KIER.

25 July - Completed draft detailed Gantt chart for Phase 1 of the Korea MARKAL Model Development Program (Appendix F). Presented seminar on "Choosing Among Future Energy Technologies." Attended dinner meeting with Dr. Paul Chung-Moo Auh, Vice President (Energy), KIER.

26 July - Together with Dr. Oh, Mr. Lee, Mr. Kim and myself, Dr. Shin reviewed the BNL job description, Phase 2 Gantt chart, detailed Phase 1 Gantt chart, and the Check List. Dr. Shin requested that I use the remaining time in Korea to begin some of the tasks identified for the visit by Dr. Oh and Mr. Lee to BNL.

27 July - Prepared "Rationale for Korean Market Penetration (Appendix G). Together with Dr. Oh, Dr. Jun, Mr. Lee and Mr. Kim, reviewed Energy Flow Charts in detail to begin identification of technologies for prototype Korea model.

28 July - Further work on "Rationale." Prepared this report to Mr. Park, UNDP.

APPENDIX A

D. Hill Work Plan — July 18, 1988

1. Review status of MARKAL model development
   - Flow Charts
   - Technology Identification
   - Technology Data Availability
   - Fuel Cost Projections
   - Energy Demand Projections

2. Specify procedure for developing MARKAL model of Korea.

3. Specify technology data requirements.

4. Provide information on coding technology data for input to MARKAL.

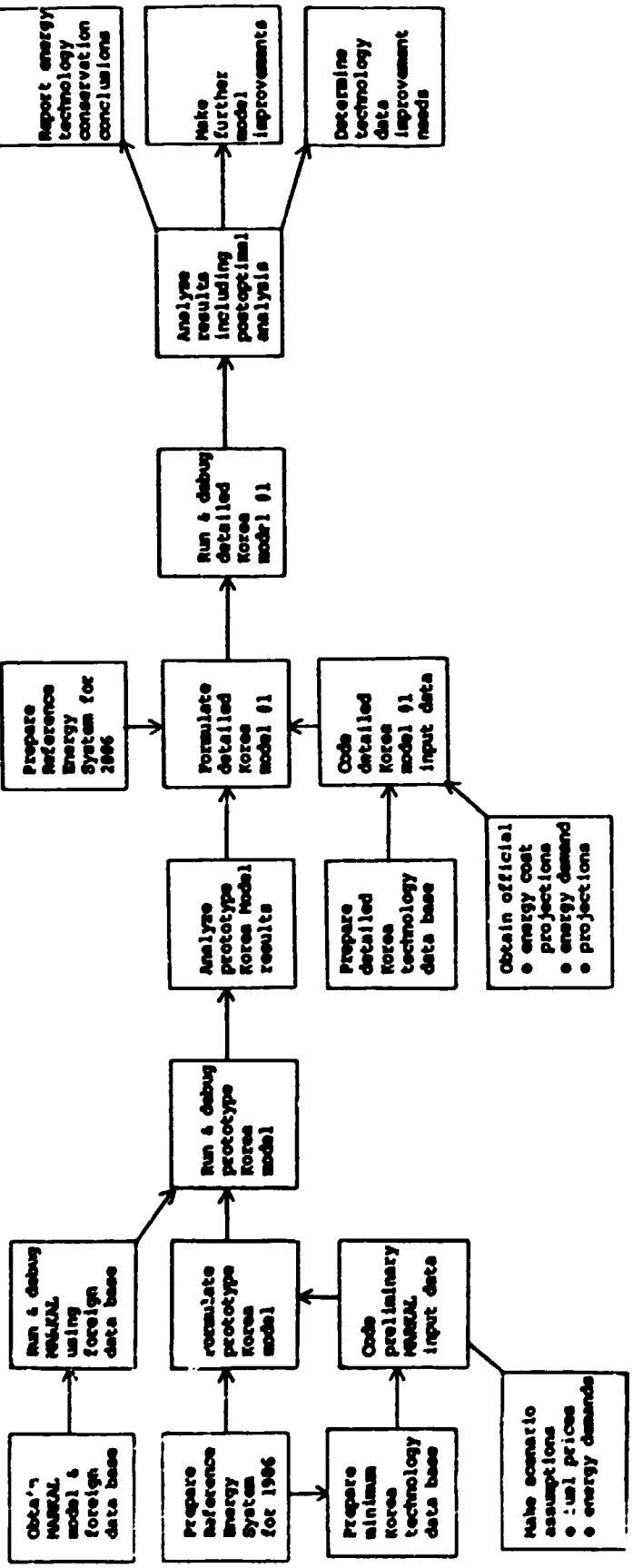
5. Respond to questions on MARKAL model development.

6. Give seminar: "Choosing Among Future Energy Technologies."

7. Prepare Gantt chart for 2-year development and use of MARKAL model of Korea.

APPENDIX B

Development of Korea MARKAL Model Logic Flow



APPENDIX C

Procedure for Developing MARKAL Model of Korea

Phase 1

Objective: Develop Prototype Korea Model that represents 1986 energy system, using borrowed data as necessary and making assumptions for future fuel prices and energy demands in order to obtain a working model.

1. Obtain Software for MARKAL Operation
   - Data handling package
   - Matrix Generation
   - Linear Programming Optimization

2. Obtain MARKAL Model and Foreign Data Base
   - Obtain Standard MARKAL on magnetic tapes from Kernforschungsanlage Jülich (KFA), FRG, suitable for VAX computer.
   - Obtain foreign data, for testing MARKAL installation, preferably FRG from KFA. (Backup: USA from BNL)

3. Run and Debug MARKAL Using Foreign Data Base
   For testing model installation

4. Prepare Reference Energy System for 1986
   Flow chart of energy imports, extraction, conversions, exports and end-use. Should be qualitatively correct in showing all 1986 energy paths. Should show quantities of energy flows in 1986. (Preferably with English labels to facilitate checking its later use.)

5. Prepare Minimum Korea Technology Data Base.
   Identify one or more typical technologies at each node of 1986 Reference Energy System. For each technology, estimate the technology characterization data required for MARKAL. (BNL "Blue Book" shows requirements.) Use best available data,* borrowing other national data as required, or make plausible assumptions. Suggested technology data sources:
   BNL Blue Book
   EPRI Technical Assessment Guide ("TAG")

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*Use the time available to prepare authoritative data insofar as possible. This will reduce the effort needed later in Phase 2, step 12, "prepare detailed technology data base."

KFA summaries of IEA/ETSAP technology characterizations (3 volumes).

(Note: Maximum market penetration in absolute values cannot be borrowed directly since the size of the market depends on the size of the country. Some preliminary judgments must be made for Korean market.)
(Note: "New" technologies may have same performance and cost as "existing" technologies, but will require upper bounds of market penetration instead of residual values).

6. Make Scenario Assumptions for Fuel Price Projections and Energy Demands.
To run the MARKAL Model, projections of the costs of fuels and energy demands are required for the time period covered by the model (usually 45 years: 9 time periods of 5-year duration). To run the prototype Korea model, these need not be authoritative. Plausible assumptions should be made. Fuel costs and energy demands should be consistent with each other and GNP projections.

7. Code Preliminary MARKAL Input Data.
The technology data from step 5 and the scenario assumptions from step 6 need to be coded in the form required by MARKAL. The form of the data is specified in the User's Guide for MARKAL (BNL/KFA Version 2.0), BNL 51701 (1988), and illustrated in its Appendix A for the FRG data base. Additional examples of data input are available on BNL microfiche for USA.

8. Formulate Prototype Korea Model.
Prototype Korea model consists of a complete MARKAL data base in which every node of the 1986 reference energy system is represented by one or more technologies. "Formulating" the prototype Korea energy model at this stage means assembling the coded MARKAL input and verifying that it is complete and corresponds to the 1986 RES.

9. Run & Debug Prototype Korea Model.
Load the prototype Korea data base into the computer and make test runs. Software should help identify infeasibilities, unbounded conditions, etc., that may interfere with obtaining an optimal solution. Continue making corrections until a feasible, optimal solution is reached.

Phase 2
Objective: Develop Detailed Korea Model that represents both the 1986 energy system and plausible future changes in order to evaluate alternative energy technologies and conservation measures.

10. Analyze Prototype Korea Model Results.
The process of debugging the prototype model & analysis of the results should serve to check the completeness of the 1986 reference energy system. Depending upon how realistic the data are, these initial results may provide some guidance for how the data base should be expanded for the detailed Korea model.

11. Prepare Reference Energy System for 2006.
Possible qualitative changes in the Korean energy system in the foreseeable future should be identified; for example, introduction of the new fuel consisting of a mixture of low grade domestic anthracite coal and imported coal used to raise the average energy content, plus the technology that burns this fuel. A hypothetical future energy system that permits the use of all such candidate technologies should be defined (suggested here for the year 2006). This would be an elaboration of the 1986 R.E.S.

12. Prepare Detailed Korea Technology Data Base.
The detailed Korea technology data base will consist of existing technologies and new technologies. The data base for existing technologies should include typical examples representing all the energy technologies needed for the 1986 R.E.S. This must include a projection of the declining installed capacity of each of these technologies as equipment reaches the end of its useful life. The data base for new technologies must include an estimate of the maximum installed capacity that might be achieved over time if the new technologies must include all candidate technologies identified for step 11.

13. Obtain Official Energy Cost Projections and Energy Demand Projections (which should be consistent with each other & GNP projections).
These can be easily changed in successive runs of the computer model to examine different scenarios of future development.

14. Code Detailed Korea Model Input Data.
Same procedure as step 7.

15. Formulate Detailed Korea Model.
Same as step 8. Here "formulating" the detailed Korea model means revising the prototype Korea model to correspond to the 2006 R.E.S and include the detailed Korea technology data base.

16. Run & debug detailed Korea Model.
Same as step 9.

17. Analyze Results Including Postoptimal Analysis. Several runs of the detailed Korea model should be made for scenarios representing a range of uncertainty in future energy costs and energy demands. The implications of various energy policies can be explored (e.g., subsidization of solar energy). Various objectives can be tested (e.g., cost minimization, oil import reduction) and tradeoffs among them examined. Various measures of the value of individual technologies and conservation measures can be used (e.g., energy saved by the technology, shadow price showing the marginal value of another unit of capacity, change in energy system cost with and without the technology). Postoptimal analysis can reveal how results may change with difference in technology costs.

18. Report Energy Technology & Conservation Conclusions. Emphasis in reporting energy technology & conservation conclusions should be on identifying the future circumstances that favor or do not favor use of the technology, rather than "picking winners." Sensitivity of conclusions to range of uncertainty in cost should be reported.

19. Determine Technology Data Improvement Needs. Sensitivity analysis in step 17 reported in step 18 may indicate that some conclusions must be hedged because of uncertainty in data. This should serve as a guide to further effort in improving the technology data base.

APPENDIX D

Check List for Technology Data Entries in MARKAL Dict./Data

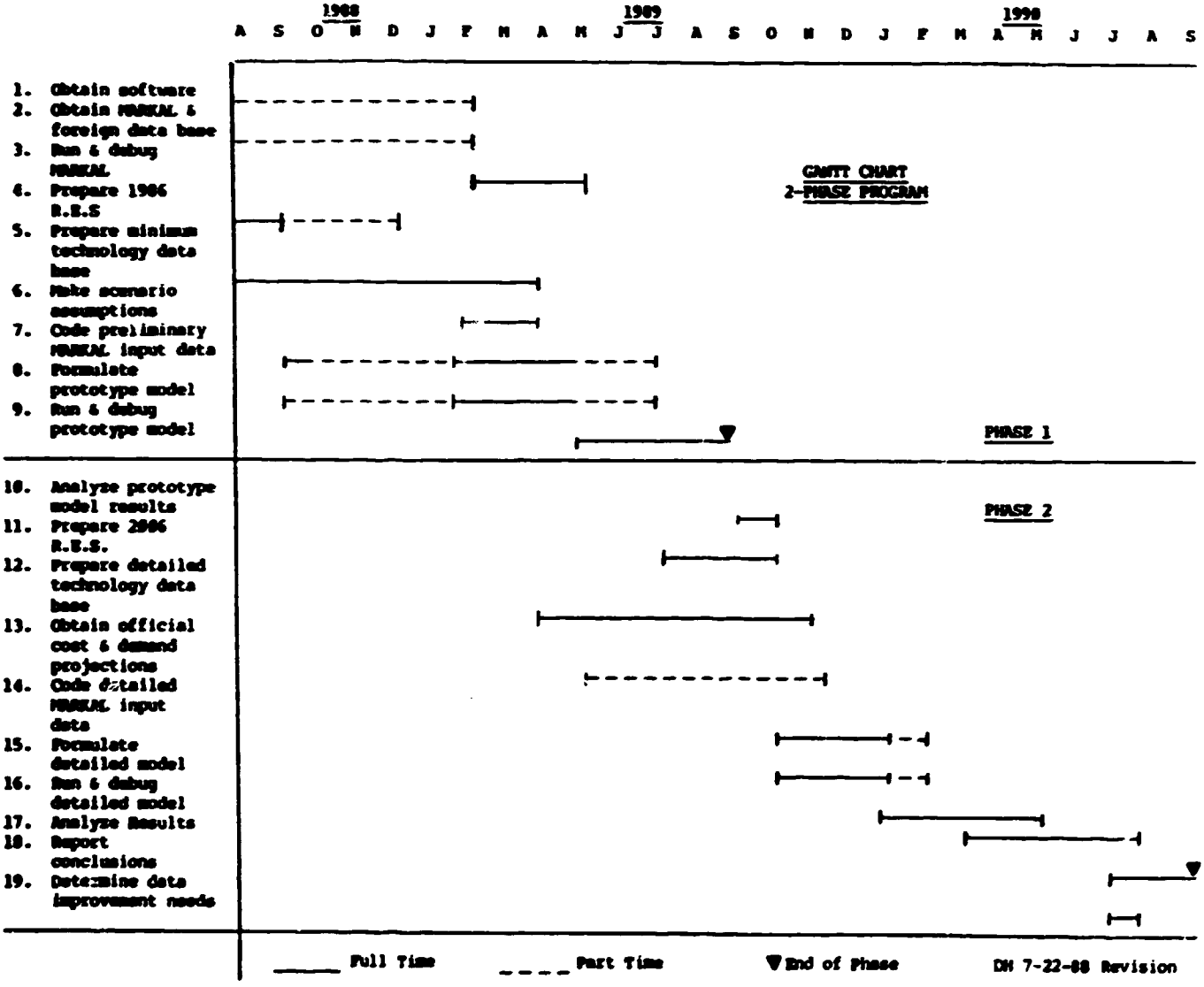
	Conversion Technologies E _ _	Process Technologies S _ _	Demand Technologies (DMD) ---	Energy Carriers (ENC) ---	Sources (SRC) ---
User-Supplied Class Lists					
BAS	B				
CEN/DCN/STG	A				
CPD/ELE/HPL/STG	A				
FOS/NUC/REN/STG	A				
HDE	B				
MLM	B				
RNT	B	B	B		
XLM	B				
DUM		B			
PRC		A			
MST		B	B		
DMD			A		
DMDENTV			A		
ECV/GAZ/LIQ/SLD				B	
EFS/ENC/ENU/ERN/ESY				A	
SRCENCP				A*	A*
Other Class Lists: DM, ENV, National, T, Year, Adratio					
User-Supplied Tables					
TCH(TCH)	A	A	A		
COM(COM)	A				
CPD(CPD)	B				
ENV(ENV)	B	B	B		B
NEWTCH	B	B	B		B
PEAK	B				
PRC(PRC)		A			
DMD(DMD)			A		
(SRC) (ENC) (P) (EXP/IMP/MIN/RNW*/STK)				A*	
Other Tables: Constant, DM(DM), Strategy, Adratio					

NOTES:

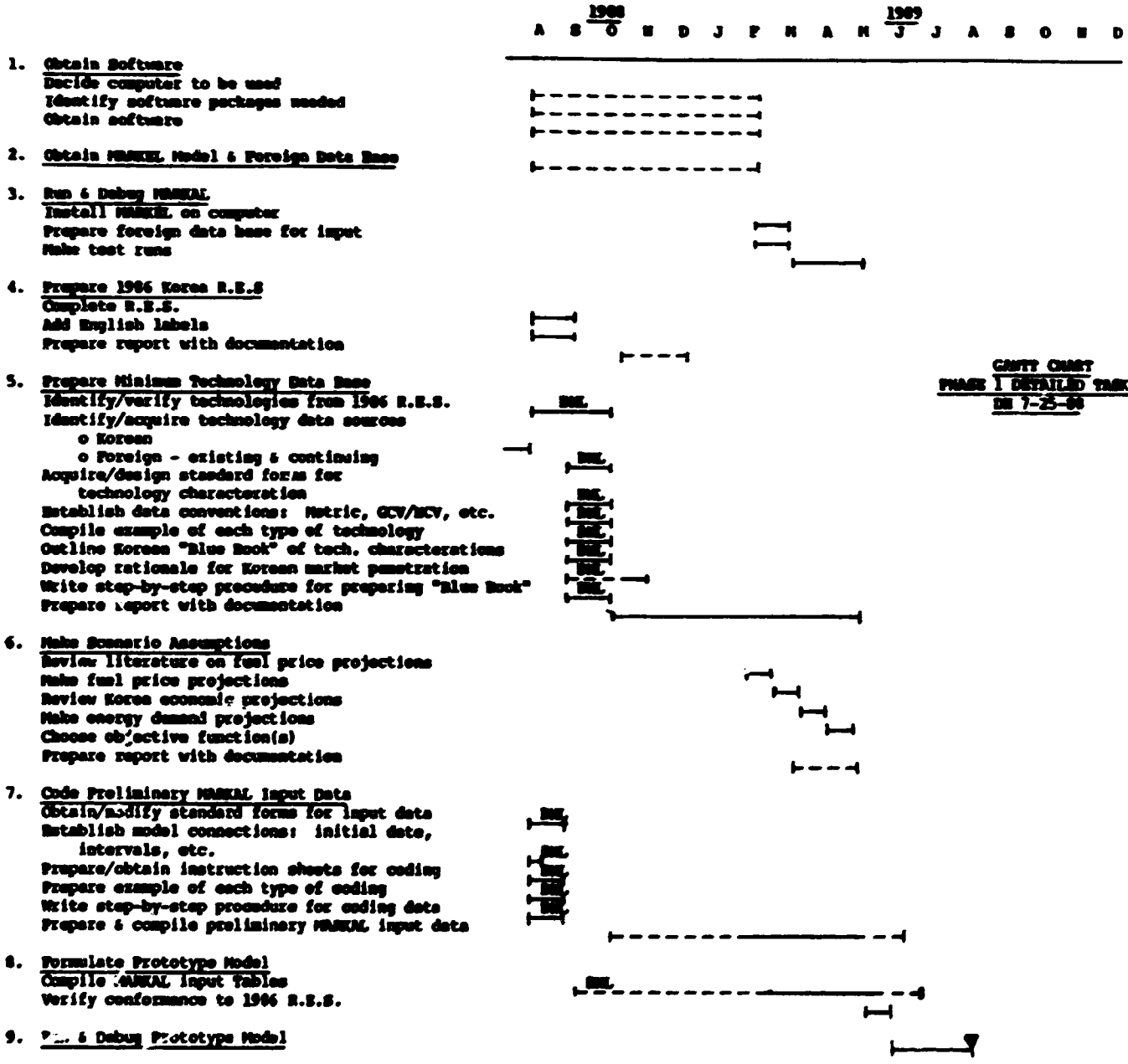
1. This check list is intended to facilitate use of User's Guide for MARKAL in preparing input data for technologies. In case of inconsistencies, follow Users's Guide.
2. A = always required B = if appropriate / = or
3. *See User's Guide, p.76, for special treatment of RNW

DH 7-22-88

APPENDIX E


1988
1989
1990
A S O N D J F M A M J J A S O N D J F M A M J J A S
1. Obtain software
2. Obtain MARKAL & foreign data base
3. Run & debug MARKAL
4. Prepare 1986 R.E.S
5. Prepare minimum technology data base
6. Make scenario assumptions
7. Code preliminary MARKAL input data
8. Formulate prototype model
9. Run & debug prototype model
GANTT CHART
2-PHASE PROGRAM
PHASE 1
10. Analyze prototype model results
11. Prepare 2006 R.E.S.
12. Prepare detailed technology data base
13. Obtain official cost & demand projections
14. Code detailed MARKAL input data
15. Formulate detailed model
16. Run & debug detailed model
17. Analyze Results
18. Report conclusions
19. Determine data improvement needs
PHASE 2
Full Time
Part Time
End of Phase
DH 7-22-88 Revision

APPENDIX F


1988
A S O N D J F M A M J J A S O N D
1989
1. Obtain Software
Decide computer to be used
Identify software packages needed
Obtain software
2. Obtain MARKAL Model & Foreign Data Base
3. Run & Debug MARKAL
Install MARKAL on computer
Prepare foreign data base for input
Make test runs
4. Prepare 1986 Korea R.E.S
Complete R.E.S.
Add English labels
Prepare report with documentation
5. Prepare Minimum Technology Data Base
Identify/verify technologies from 1986 R.E.S.
Identify/acquire technology data sources
o Korean
o Foreign - existing & continuing
Acquire/design standard forms for technology characterization
Establish data conventions: Metric, GCV/NCV, etc.
Compile example of each type of technology
Outline Korean "Blue Book" of tech. characterizations
Develop rationale for Korean market penetration
Write step-by-step procedure for preparing "Blue Book"
Prepare report with documentation
6. Make Scenario Assumptions
Review literature on fuel price projections
Make fuel price projections
Review Korea economic projections
Make energy demand projections
Choose objective function(s)
Prepare report with documentation
7. Code Preliminary MARKAL Input Data
Obtain/modify standard forms for input data
Establish model connections: initial date, intervals, etc.
Prepare/obtain instruction sheets for coding
Prepare example of each type of coding
Write step-by-step procedure for coding data
Prepare & compile preliminary MARKAL input data
8. Formulate Prototype Model
Compile MARKAL Input Tables
Verify conformance to 1986 R.E.S.
9. Run & Debug Prototype Model
GANTT CHART
PHASE I DETAILED TASKS
DH 7-25-88

APPENDIX G

Rationale for Korean Market Penetration - First Thoughts

The market penetration of a new technology may be limited by either of two factors:

(1) On the production side, the maximum rate at which a new technology can be introduced due to constraints on industrial capacity expansion or rate of imports;

(2) On the demand side, by socioeconomic determinants of growth in the demand that the technology satisfies.

The market penetration of a new type of automobile, for example, could be limited either by:

(1) How quickly it can be put in production and the maximum rate at which it can be manufactured, or

(2) The Korean domestic demand for automobile transportation, which will be determined by the income level of the population and other socioeconomic factors that may influence the desirability of owning a car rather than using public transportation.

These two limitations enter the formulation of the MARKAL model in different ways:

(1) The limit on production rate is specified for the individual technology as BOUNDUP (upper bound) in the TCH (TCH) table.

(2) The limit on MARKAL demand for auto transportation is specified as a demand projection into the future in the DM (DM) Table.

The first (BOUNDUP) becomes part of the technical matrix, that is, the set of inequations that constitute the linear program. The coefficients in this matrix (such as BOUNDUP) are ordinarily considered as fixed.

The second MARKAL input (DM (DM)) is part of the "right hand side" of the linear program. The right hand side is a set of assumed constraints that must be satisfied by the MARKAL solution. A variety of "right hand sides" are usually assumed as part of the different scenario assumptions explored in a set of MARKAL runs.

Thus, specifying BOUNDUP is a relatively straightforward estimate characteristic of the technology and its manufacture. It is clearly a technical judgment or estimate.

On the other hand, specifying DM (DM) is a more complex socio-

economic problem that is not primarily technological. (And it may be more interesting. Will Korean demand patterns follow those of Japan as its industrial development continues? Will the government influence automobile ownership and use through taxes on cars and fuel?)

In applying the Korean MARKAL model, a choice will have to be made among these policies:

(1) Develop a capability for estimating demands.

(2) Depend upon demand forecast provided by others. (Note: it is doubtful that any economic forecasting group will estimate 45 years into the future. The usual practice in the USA has been to take "medium term" forecasts and extrapolate them.)

In either case, it will be desirable to investigate a wide range of demand projections to establish the sensitivity of technological conclusions to projected demand assumptions. (Note: Energy demand projections are normally linked to a specific set of energy price projections.) U.S. experience has been that technological conclusions are more sensitive to variations in demands than to prices as such.

There is a literature on market penetration. An example is the Fisher-Pry relationship that specifies mathematically a growth curve in market penetration that is S-shaped (initial growth at an increasing rate changing to a decreasing rate of growth as market saturation is approached). This curve is based on empirical study of past experience. Believers think that it is possible to estimate total market penetration after the first 5 or 10% of growth is observed.

This past experience of course, is the result of a meeting of supply and demand, so that it is not entirely clear (at least at the beginning of market growth) whether it is supply or demand that constrains growth.

In my opinion, these studies have been useful in revealing how quickly new technology spreads in a large country or a large geographical region. (Examples: automobile automatic transmissions and air conditioning, diesel locomotive, jet aircraft). I should think that the time from market introduction to market saturation would be much, much shorter in a small country, particularly if the government favored it.

Rationale for Korean Market Penetration Second Thoughts

In the previous discussion, a clear distinction is made between production constraints, for example, on a new model automobile, and demand projections, illustrated by the example of forecasting the market for all automobiles. However, projecting the market penetration for a new model auto may not be as simple as estimat-

ing its production constraints. Within the market for all automobiles, the growth in market penetration of a new model may be subject to demand limits as well as production limits.

For example, in the past in the U.S., innovations in new models have included automatic transmissions, air conditioning, and diesel engines. None of these penetrated the entire market for automobiles. Each probably traced out its own "Fisher-Pry" S-curve in which at least the latter part of the S-curve was due to a saturation in demand for this feature.

In the future, there will undoubtedly be other innovations in automobile design (possibly, 4-wheel steering or continuously variable transmissions). These too can be expected to reach a market saturation that is less than 100% of the automobile market.

The implication of this is that the estimation of the upper bound of market penetration (BOUNDUP) cannot be simply a matter of production constraints, as stated in "First Thoughts..." but must take into account limitations on demand.

More thought needed.