3.2.16.3 Electricity rates

OPERA deals with energy calculations for monthly mean values. This means that it is necessary to present the energy prices in monthly mean values. When district heating was concerned, no difficulties emerged but this is not the fact when electricity rates are considered. There are two different rates that might be applicable in Malmö, Sweden.

3.2.16.3.1 Fuse tariff

The fuse tariff is applicable when the necessary fuse size is lower than 250 A. The demand charges are presented first in the input data file and they are:

Fuse smaller than	Demand charge
16 A	830 SEK/Year
20	1 030
25	1 230
35	1 640
50	2 060
63	2 380
80	2 900
100	3 520
125	4 300
160	5 420
200	6 760
250	8 400

The charges and the fuse sizes are stored in an two arrays, ABONA(12) and SAK(12).

The energy cost depends on the season and the time of use during the day. The following tariff is used, stored in two variables HELP and LELP.

Nov - March, Monday - Friday, 0600 - 2200	0.515 SEK/kWh
Otherwise	0.245 SEK/kWh

Taxation of 0.072 SEK/kWh is included in the price. Note that the taxation will be changed from 1990 03 01.

Due to the monthly mean values used in OPERA, it is necessary to transform the rate above to one that reflects a monthly mean price. This is made by the program, in subroutine TARIFF, but OPERA must know how many working hours and free hours there are each month, and the hours with low and high price. The high and low price hours are stored in two arrays called HHOURS(12) and LHOURS(12). The values in the input data file are:

Month	High price hours	Low price hours	Month	High price hours	Low price hours
January	352	392	July	336	408
February	320	352	August	368	376
March	368	376	September	336	384
April	320	400	October	352	392
May	368	376	November	352	368
June	352	368	December	336	408

Note that the high price hours are considered as those from 0600 and to 2200 during working days also in the summer. This is so because of the demand tariff below. The applicable price is implemented in the subroutine.

3.2.16.3.2 Demand tariff

If the fuse size is higher than 250 A the demand tariff is applicable. The tariff is designed as follows:

Fixed fee	6000 SEK/Year	FASTAVG
Subscription fee	55 SEK/kW · Year	ABONAVG
Power fee	245 SEK/kW · Year	EFFAVG

The energy tariff is more complicated than the earlier one:

Energy price:

November - March,	Monday - Friday,	0600 - 2200	0.333
	Otherwise		0.184
April, September,	October, Mon. - Fri.	0600 - 2200	0.184
	Otherwise		0.146
May - August,	Monday - Friday,	0600 - 2200	0.130
	Otherwise		0.107

Taxation is not included in these prices, but for residential space heating purposes it is 0.072 SEK/kWh. Note that taxes are included in Figure 3.

As shown above there are 5 price levels. These levels are stored in an array called ENEDEM(5) and implemented in the input data file with the high price first, taxation included.

The electricity tariffs end the input data file.

As can be found, there are a lot of values to be presented to OPERA. It is thus again recommended to copy and rename the file when a new building is considered, and then to change the values in the file one by one, if needed. An extra comma or point, or an integer when OPERA expects a floating point, will terminate the program. Remember also the figures written out by OPERA which will make it easier to locate errors in the data file.

4. USING THE OPERA MODEL

When a computer program is to be used it is important that the operator is familiar with it, both in order to use it properly and also how to interpret the result. Here it is explained how to run the program and how to understand the output on the screen or at the printer. The input file shown in Figure 3 is used as an example, and the tables presented look the same in this manual, as on the screen. If the figures in the tables differ from the ones presented in the manual there is something wrong, or the input data file has been changed.

4.1 How to start

The OPERA model in this version is elaborated for use in the IBM PC or close compatibles. It is assumed that a printer is connected to the computer, using the port PRN, see the OPEN statement in the beginning of the FORTRAN code. Mostly this port is the same as LPT1 and normally no changes are needed. However, in the text below, the screen is supposed to be the output device.

The program disk shall be put in the computer, normally in drive A, and the programs and data be copied to the hard disk of the system. There is no installation program and it is assumed that all the programs and the data files are put into the same directory. Further it is assumed that a floating point co-processor is present. If not, it is not necessary to use special versions of the program files, but the program will operate much slower.

The following program and data files shall be present:

- OPERA.EXE,	the main program for floating point processors
- HOUSE.DAT,	the data file in Figure 3
- OPERA.TXT,	the first text output from OPERA
- SUB.EXE,	for simulating the Swedish subsidy system
- SUB.C,	- " -

- SYS.C,	for simulating the Swedish subsidy system
- LEAST.C,	- " -
- LOAN.DAT,	shows the subsidy system
- SUB.DAT,	a converted input data file for subsidies
- OPERA.FOR,	source code in FORTRAN, main program
- OPSUB.FOR,	source code in FORTRAN, subroutines
- SORAD.EXE,	for solar calculations
- SUN.DAT,	for solar calculations
- SORAD.C,	source code in C, solar radiation program
- BIVAL.EXE,	for discrete optimization of bivalent heating systems and time-of-use tariffs
- BIV.DAT	discrete optimization input file
- BIVAL.FOR,	source code in FORTRAN, bivalent system optimization
- GRAPH.EXE,	for the graphic presentation
- DUR.DAT,	data file for the duration graph
- GRAPH.C,	source code in C, graphic presentation

When the files are stored on the hard disk type OPERA and press the RETURN key and the program will start. If everything has worked fine a question on the screen asks for the applicable input data file. Here the file is called HOUSE.DAT. After typing this, press the RETURN key, and the program will start calculating the optimal strategy of the building. The program can be halted by a control-S, for a closer look at the output.

4.2 Basic output and how to interpret it

After the initial text presenting the program, and some figures from 1 to 8, showing that the input data file is read properly, the program output starts with the input data, followed by an energy balance which has been calculated from the outdoor climate data, the thermal status of the building, and the desired inside temperature, se Figure 6.

In the case studied here, the total number of degree hours is 114 008. This value is calculated, using expression (8), with the assumption that one degree hour is generated for each hour the desired inside temperature exceeds the outdoor temperature.

```
                         ENERGY BALANCE
                         ==============

 MONTH  DEG.-   ENERGY-   HOT -    FREE     SOLAR  UTILIZ.  FROM    INSUL.
 NO     HOURS   TRANSM    WATER    ENERGY   HEAT   FREE     BOILER  OPTIM.
---------------------------------------------------------------------------
   1    15996.  32893.   3500.    4167.    1201.   5368.   31026.  32893.
   2    14713.  30254.   3500.    4167.    2609.   6776.   26978.  30254.
   3    14582.  29987.   3500.    4167.    6078.  10245.   23242.  29987.
   4    10800.  22209.   3500.    4167.    8998.  13165.   12544.  22209.
   5     7440.  15299.   3500.    4167.   12717.  15299.    3500.      0.
   6     4320.   8883.   3500.    4167.   13200.   8883.    3500.      0.
   7     2827.   5814.   3500.    4167.   12933.   5814.    3500.      0.
   8     3199.   6579.   3500     4167    10900.   6579.    3500.      0.
   9     5400.  11104.   3500.    4167.    7712.  11104.    3500.      0.
  10     9002.  18512.   3500.    4167.    4109.   8276.   13736.  18512.
  11    11592.  23837.   3500.    4167.    1561.   5728.   21609.  23837.
  12    14136.  29069.   3500.    4167.     778.   4945.   27623.  29069.
---------------------------------------------------------------------------
TOTAL  114008. 234440.  42000.   50004.   82796. 102183.  174257. 186761.

              TRANSMISSION COEFFICIENT =  1602.30 W/K
              VENTILATION COEFFICIENT  =   454.05 W/K
```

Figure 6. Energy balance calculation in OPERA

The equation used for the degree hour calculations is:

$$DH = \sum_{n=1}^{12} (T_i - T_{s,n}) \cdot \tau_n \qquad (8)$$

where DH = the number of degree hours for one year

n = the number of the month

T_i = the desired inside temperature

$T_{s,n}$ = the mean outside temperature at month n, site s

τ_n = the number of hours in month n

The process of calculation is described in detail in [2 p 43], while a more scientific discussion about the degree hour concept can be found in [21].

In this case study, the monthly mean temperature in January is - 0.5 °C and the desired inside temperature is 21 °C, see Figure 3. The difference is 21.5 °C, and the number of hours in January is 744. Subsequently the degree hour number is:

$$744 \cdot 21.5 = 15\,996$$

The degree hour calculations are elaborated in a subroutine called GRADTIM, see appendix B, and the numbers of degree hours for each month are stored in an array, called GRAD(12), for later calculations on e g differential rates or tariffs.

It is common to use an indoor base temperature, which is set lower than the desired, for calculating the number of degree hours. In Sweden, this temperature is often set to 17 °C, assuming that free energy from appliances etc shall meet the demand up to 20 °C. In OPERA the energy balance subroutine takes care of the free energy considerations.

OPERA also calculates the total transmission and ventilation coefficients for the building. The coefficiants are called TRANS and VENT, see the code in appendix A, and they are calculated as:

$$\mathrm{TRANS} = \sum_{n=1}^{m} (U_n \cdot A_n) \qquad (9)$$

where n = the building part indices
m = the number of building parts
U = the thermal transmittance
A = the area for the building parts.

and:

$$\mathrm{VENT} = H \cdot BA \cdot RN \cdot \rho \cdot cp \qquad (10)$$

H = the distance between the floor and ceiling in an apartment

BA = the net dwelling area
RN = the number of air renewals in the apartments
ρ = the density of air and
cp = the heat capacity.

A more detailed discussion about formula (9) and (10) can be found in [2].

After this, the energy losses in the building are calculated by multiplying the total transmission and ventilation factor, TRANS + VENT, by the number of degree hours. In this case the result will be:

$$15\,996 \cdot (1\,602 + 454) = 32\,893\,000 \text{ Wh}$$

Note that the coefficients, TRANS and VENT, are presented by OPERA in the energy balance table on the screen, and that the coefficients in the code sometimes have slightly different names such as TRANSEF, TRANSEN etc.

The need for heating domestic hot water and the above value are added while the free gains are subtracted. The demand in January will thus be:

$$32\,887 + 3\,500 - 4\,167 - 1\,201 = 31\,026 \text{ kWh.}$$

Note that the figures above have been truncated for simpler reading.

The total gains are subtracted from the total losses and the result is tested whether negative or not. If negative, the gains are bigger than the losses and the heating equipment can be turned off during the whole month, for space heating purposes. As shown in [1] this is important to consider, when deciding the proper optimization values for both the heating system and the envelope retrofits. The heating system shall only be optimized for the heat actually produced in the facility, and the free energy over the year has to be excluded from the total energy losses in the building.

The envelope retrofits, however, shall not be optimized for the same amount of energy. Most of the year the free energy is valuable. If there is no free energy, the heating system must produce the heat. Only during the months when the heating system does not work with space heating, the free energy is unimportant. It only raises the temperature inside the building to an uncomfortable level and then the free gains are of course useless.

Because of this it is necessary to recalculate the energy balance every time a new retrofit is implemented in the model. OPERA, however, does only present one of the balances on the screen or printer when basic output is selected. There is also a value, showing the used part of the free gains. During the summer, see Figure 6, there is a surplus of free heat and thus more free gains are utilized during May than during June.

The program continues by calculating the retrofit strategies for each heating equipment, see Figure 2. If something happens that the operator should be notified about, there will be an extra line of text on the screen. In our case, weatherstripping was not found profitable when heating system #6, i.e. the natural gas boiler, was considered. If the operator finds this peculiar there might be a need for examining this fact in detail.

There are also other values presented during the operation. Normalized energy prices for district heating and electricity are shown. These prices have to be used if the design of e.g. a differential district heating tariff shall be compared with a fixed rate. See also chapter 3.2.16.1 and .2.

OPERA continues with calculating the different retrofit strategies and after this is done, selects the optimal one, or at least the almost optimal. This strategy is presented in further detail. OPERA tells the operator which building retrofits are selected and the heating system they shall be combined with. If insulation measures are chosen the thickness of the extra insulation is presented. For each implemented retrofit the total design load, the total transmission and ventilation coefficient, the energy need for one year, the inevitable retrofit cost and the building and/or ventilation retrofit cost can be found.

Also the resulting LCC is of course presented and the sum is split up. If the example in Figure 3 is run, the output is presented as follows:

The optimal LCC = 1 197 530 SEK
Salvage value, existing heating system = 20 533 SEK
Inevitable retrofit cost = 253 788 SEK
New heating system cost, pipes excluded = 86 840 SEK
Cost for pipes = 12 870 SEK
Energy cost = 627 017 SEK
Insulation cost = 188 760 SEK
Connection fee = 7 721 SEK

OPERA also calculates the LCC for the building when all the retrofits found optimal are introduced. The difference between this sum and the earlier assumed LCC is shown and in this case it is zero. The optimal building retrofits, i.e. triple-glazing the east and west windows, did not interact.

There is also a table presented by OPERA, showing the different building retrofit strategies, and the LCC for each heating system. The table is presented in Figure 7. On the horisontal axis the heating systems under consideration are presented. The vertical axis first shows the LCC for the building with no envelope retrofits and then the savings that are assumed for each retrofit. In Figure 7 the first value, i.e. 1.48, shows the LCC for the existing heating system if no building or ventilation retrofit at all is introduced. The next value below 1.48 is .00 showing that attic floor insulation was not profitable and thus not implemented. The same happens for floor insulation, but external wall insulation gives 0.05. This means that the insulation is assumed to save 0.05 MSEK for the period in consideration. One more building retrofit is selected, viz. triple-glazed windows, which is assumed to save 60 000 SEK for the optimization period. When the existing heating system is dealt with the resulting LCC is will become 1.36 MSEK.

```
                  ***  LCC TABLE FOR  BASE CASE                  1.00  ***
                       VALUES IN MSEK
                  ===================================
                EXIS.  NEW   ELE.  DIST. GR.W  NAT.  TOU   TOU   BIV.  BIV.O.
                SYST.  OIL   HEAT  HEAT  HEAT  GAS   DIST  ELEC. GR.HP AIR HP
 ----------------------------------------------------------------------------
 NO BUILD. RETR. 1.48  1.54  1.69  1.45  1.57  1.23  1.45  1.69  1.38  1.48
 SAVINGS:
 ATTIC FL. INS    .00   .00   .01   .00   .00   .00   .00   .01   .00   .00
 FLOOR INS.       .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
 EXT. WALL INS.   .05   .05   .11   .04   .06   .00   .04   .11   .00   .03
 INS. WALL INS.   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
 TRIPLE-GLAZING   .06   .07   .09   .06   .08   .04   .06   .08   .05   .06
 TRIPLE-GL. L.E.  .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
 TR.-GL. L.E. G.  .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
 WEATHERSTRIP.    .01   .01   .02   .01   .01   .00   .01   .01   .00   .00
 EXH. AIR H. P.   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
 ----------------------------------------------------------------------------
 SUM. OF RETRO.  1.36  1.41  1.46  1.34  1.42  1.20  1.34  1.48  1.33  1.39
 SUM. OF COMB.   1.36  1.41  1.46  1.34  1.42  1.20  1.34  1.46  1.33  1.39
 ----------------------------------------------------------------------------
DISTRIBUTION:
 SAL. OLD BOILER  .00   .02   .02   .02   .02   .02   .02   .02   .02   .02
 NEW BOIL. COST   .08   .10   .03   .06   .28   .09   .06   .03   .25   .31
 PIPING COST      .00   .01   .00   .01   .16   .01   .01   .00   .07   .01
 ENERGY COST      .60   .59   .62   .56   .28   .63   .56   .61   .34   .35
 CONNECTION FEE   .00   .00   .00   .01   .00   .01   .01   .00   .00   .00
 BUIL. RETROF. C  .43   .43   .54   .43   .43   .19   .43   .54   .40   .44
 INEVITABLE COST  .25   .25   .25   .25   .25   .25   .25   .25   .25   .25
 ============================================================================
```

Figure 7. LCC table presented by OPERA

The lowest LCC, however, is achieved when a natural gas system is introduced. If that is the case, the external wall retrofit is unprofitable and triple-glazing is the only building retrofit selected by the model. The total new LCC is assumed to be 1.20 MSEK or 160 000 SEK cheaper than the earlier discussed strategy.

The table in Figure 7 is used by the operator in order to compare the different strategies to each other. It is also possible to see the distribution between the different costs for all the heating systems under consideration, but in less detail than the table for the optimal strategy.

4.3 Sensitivity analysis

The optimal strategy calculated by OPERA is only valid as long as the input data do not change. Some of the input data however, cannot be chosen with an absolute accuracy, and thus it might be valuable to compare the result from a number of OPERA runnings. The fact is that, if the value on ST1, see Figure 3, is set to 0, the model generates more tables, and automatically, optimization periods from 10 - 50 years, interest rates from 3 - 11 % and annual energy escalation prices up to 3 % are presented. It is, however easy to change the code if more or less tables are wanted, see the last part, near the END statement in the main program code, appendix A.

By examining these tables some basic facts about the optimization can be found. If one of the input data is increased, say by 10 %, the resulting LCC might be:

- lower
- higher
- not affected at all

One example of lower LCC for an increased value is the interest rate. If the rate is increased the LCC gets lower, which could be found by studying formula (1) or (2) above. An example of the opposite can be found by increasing the optimization period. With a longer period the LCC will be higher. The third way of influence can be shown by increasing the electrical boiler cost. If this is increased, nothing happens to the optimal LCC because the electrical boiler was not optimal from the beginning.

Unfortunately it is not possible to say which of the data is of the greatest interest to examine. The answer to this depends on the problem under consideration. One example of this can be the price of the electrical boiler. If the price for electrical energy is high, the system will never be chosen by the model, and different cost functions for electrical boilers are not interesting. If, however, the energy cost is decreased, the electrical boiler might be of interest in some combinations of the input data. Fortunately, this combination, may be assumed to occur only in the academic world, and can thus be excluded from future considerations.

Other times the resulting LCC for different strategies might be very close. Looking at only one criterion it will be difficult to choose the optimal solution. If it is expected that one of these solutions will be very rare, because of its price etc., it is better to choose a more robust solution even the cost is somewhat higher. Such considerations, however, are very hard to build into the model where the problem must be solved in a mathematical way, and thus there is a need for a skilled operator as well.

One way to present the situation is a kind of LCC mapping, see Figure 8. The LCC has been depicted for a number of values for the two variables and the optimal strategy is shown for each combination. Note that it is not the case presented in Figure 3 that is depicted.

More about the sensitivity analysis subject can be found in e.g. [1].

4.4 Practical session

In order to illustrate the work with the OPERA model, the building presented in Figure 3 is now examined. When the table in Figur 7 is presented, consider the figures shown by OPERA. As can be found, the natural gas heating was the optimal solution combined with triple-glazed windows. No other building retrofit was found profitable. The new windows were assumed to save 40 000 SEK for the optimization period, while changing the heating system from the existing oil-boiler to the natural gas system decreased the LCC from 1.48 to 1.23 MSEK.

It might also be important to consider the other strategies, especially if they get very close to the optimal one. In this case, the bivalent heating system combined with triple-glazed windows was the closest one, with a LCC of 1.33 MSEK. The bivalent system was in turn followed by district heating combined with external wall insulation and triple-glazed windows. It is obvious that it is the heating system retrofits that are important while building measures are less profitable. This is a very common result in OPERA runnings. At least in Sweden, the heating system should thus be much more emphasized than is the case today. .

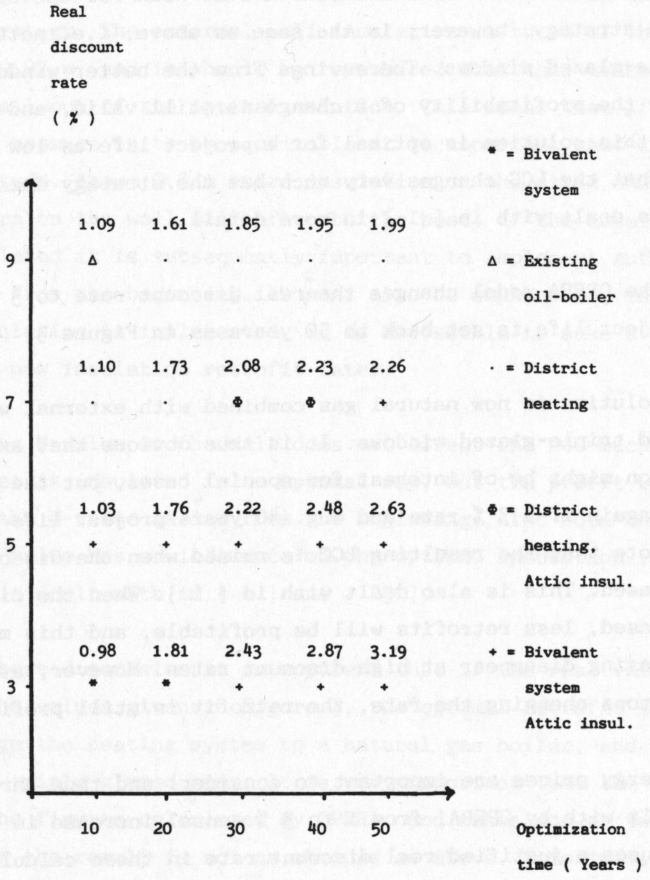

Figure 8. Bivariate sensitivity analysis [22]

When the result is as clear as this, it is no point in making closer examinations of the other strategies. No interaction could be found between the building retrofits because only one was chosen and normally the program can be terminated which also is the default.

It could, however, be of interest to consider what will happen if the project life or the discount rate are changed. If the variable ST1 is set to 0 instead of 1, the program will produce more scenarios. First the project life is decreased by 10 years. When a project life of 40 years is considered the LCC is decreased to 1.14 MSEK for the optimal solution. The strategy, however, is the same as above, i.e. natural gas and triple-glazed windows. The savings from the better windows is decreased but the profitability of a change is still valid, and the fact is that this solution is optimal for a project life as low as 10 years. Note that the LCC changes very much but the strategy does not, a fact that is dealt with in [1] in more detail.

After this, the OPERA model changes the real discount rate to 3 %, while the project life is set back to 50 years as in Figure 3.

The optimal solution is now natural gas combined with external wall insulation and triple-glazed windows. It is thus obvious that external wall insulation might be of interest for special cases, but the asset is withdrawn again if a 3 % rate and e.g. 40 years project life is dealt with. Note that the resulting LCC is raised when the discount rate is decreased. This is also dealt with in [1]. When the discount rate is increased, less retrofits will be profitable, and this makes the triple-glazing disappear at high discount rates. However, at 9 % where OPERA stops changing the rate, the retrofit is still profitable.

Escalating energy prices are important to consider, and thus three cases are dealt with by OPERA, from 1 to 3 % annual increase in real terms. OPERA uses a justified real discount rate in these calculations and this justified rate is calculated as shown in expression (3). Note however, that for high escalation of the energy prices and low real discount rates the justified rate will become negative but this will nevertheless work fine. When 1 % annual energy price escalation occurs, external wall insulation will be a part of the optimal solution, while attic floor insulation and weatherstripping will be profitable if the energy prices increase faster than ca. 3 % per year. It is also important to consider that as long as the optimal solution is encountered, the interaction between these four building and ventilation retrofits is very small, about 4 000 SEK for the 50 year period, and this interaction could therefore be neglected.

It could also be interesting to consider what amount of insulation should be implemented if the retrofit shall be included in the optimal strategy. The external wall insulation is to be of the magnitude 0.07 m, and it should be remembered that this measure is close to fall out of the optimal solution. This means that if an insulation measure is to be profitable it is important that it has some magnitude. About 0.2 m extra insulation on the attic and 0.1 to 0.15 m extra on the wall will often be the best. If the asset is to be extra insulated it is subsequently important to implement sufficient insulation from the beginning. It must also be emphasized, that if too little insulation is implemented, it is impossible to make a profitable new insulation retrofit later.

The existing U-value on the wall does not affect the LCC much as long as the asset is insulated in an optimal way, but the profit will vanish if the U-value is low from the beginning. Also note that the existing U-value has no influence on the optimal insulation level, a fact that is dealt with in [1] and [23].

From the above discussion it is apparent that if the real values are close to the values given in Figure 3, the optimal retrofit solution is to change the heating system to a natural gas boiler, and change windows to triple-glazed ones. It is very important that the operator examines the figures calculated by OPERA, and makes one or two extra runnings if the result is not as obvious as above. Sometimes, several different strategies give almost the same LCC and then other than LCC reasons have to determine the best retrofit strategy.

4.5 Understanding the FORTRAN code

In appendix A the main program FORTRAN code is presented. Here it is not possible to show the design of FORTRAN programs. The interested operator must find the knowledge elsewhere. However, it is shown how the OPERA program is designed in order to provide the necessary information for the operator to change the code and subsequently get the information which might be needed for some special cases not dealt with in the original model output. The program is split into two divisions, one for the main program and one for all the subroutines, shown in appendix B. The reason for this is that once the subroutines have been transferred, or compiled to the computer's machine language there is no need for compiling them again unless they have been changed. This is valid also for the main program. If one of the subroutines is changed, it might not be necessary to compile the main program once again. This will save time when changes are made in the code.

The program is developed with the FORTRAN 77 standard and almost no changes are necessary if different computers are used, but one or two exeptions must be mentioned. The code contains some variables with longer names than FORTRAN 77 approves. Many compilers have special commands for solving such problems and in e.g. MICROSOFT FORTRAN 4.0 so called metacommands can be used. The default in the version 5.0 is 31 significant characters.

There might also be some problems with the input/output statements in the OPEN statements when external files are to be read or written to. The operator must consult the manual of the specific compiler for such problems. Some compilers are not very sensitive for the way characters or figures are written in the input data file. Integer values might thus be interpreted as such even if a floating point is actually written. As mentioned earlier the compiler used here must find the correct form.

The code is originally developed in a NORD 570 computer, but the code shipped with the disk is changed so it will compile without any problems when MICROSOFT FORTRAN 5.0 for PC is used. It must be emphasized that programming mistakes are easily made if the code is changed by novice programmers. Sometimes the errors are easy to discover but other times the errors will only occur at very special occasions and are therefore very hard to find. It is recommended not to change the original programming code but instead to use a copy of it given a new name. A debug program will then be very useful for comparing the two versions. Setting the output parameters in clever combinations might also be a fine alternative.

Further it must be noticed that some of the comments in the code still are in Swedish. It has not been possible to change all of them into English but the mostly used parts are translated. All the default output is in English and further, all the new subroutines.

4.5.1 The main program

The main program code, which contains about 3 000 lines, starts like all FORTRAN programs by declaring all variables, dimensioning statements and so forth. After the OPEN statements, the program starts reading the input data file and proceeds by writing all the input data on the screen or at the printer depending on the variable U. If U equals 0, no text at all is shown, if it is 1 the screen takes care of the output and if it equals 3 the printer starts working.

The calculations start at about line 450 and what happens first happens is that the LCC for the existing building is elaborated. This part of the program ends at about line 760 and the LCC is stored in a variable called TOTNUVB(Y) where Y shows the number of heating system. When the existing heating system is of concern, Y will equal 1.

The program will now implement a retrofit and the first one is attic floor insulation. There are four different insulation retrofits, four window retrofits, from double to triple-glazed windows for each orientation, weatherstripping and exhaust air heat pumps. The program will then check if still better windows, like triple-glazed windows with low-emmisivity coatings, are profitable.

The insulation and window retrofits are mixed in the code but weatherstripping starts at about line 1 300 and exhaust air heat pumps at about line 1 430. The first heating system is evaluated approximately about line 1 720 and the new heating system calculations start at label 700 again. When all the heating systems are dealt with the cheapest strategy is found by a routine at about line 1 900. All the candidates for the optimal strategy are then implemented and the combined retrofit LCC is evaluated. This is accomplished at approximately line 2 770.

The remaining programming lines deal with the number of tables that OPERA provides for different real discount rates, project periods and escalating energy prices. Note the lines in the vicinity of 2 780 where it is possible to evaluate if the LCC will decrease if more or less insulation is implemented because of the interaction between the retrofits.

4.5.2 Subroutines

The second part of the program contains the subroutines called from the main program, see appendix B. There are 10 different routines:

NUVARDE	Present value calculations
SKALROT	Inevitable retrofit calculations
TABELL1	Writes the retrofit strategy tables
TAXOR	Calculates normalized rates etc.
GRADTIM	Degree hour calculations
VARAKT	Duration graph calculations
BIOPTIM	Bivalent system optimization
ENEBAL	Energy balance calculations
TABELL2	Writes energy balance table

TARIFF	Transfers real tariffs to montly mean values

In all of these tables it is possible to set the U variable to e.g. 1 and get out the necessary calculation results for scrutinizing the optimization process. Note that some of the subroutines are called several hundred times, and because of this it might be hard to select only these values of interest. It might often be better to include an IF statement in the main program, set the U variable there, and let the subroutine CALL transfer the value.