Pre-processing module of HEEP

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Pre-processing module of HEEP

1. Procedure to start the programme

Select- *Start, HEEP, HEEP-PRE*

The programme starts with the following screen

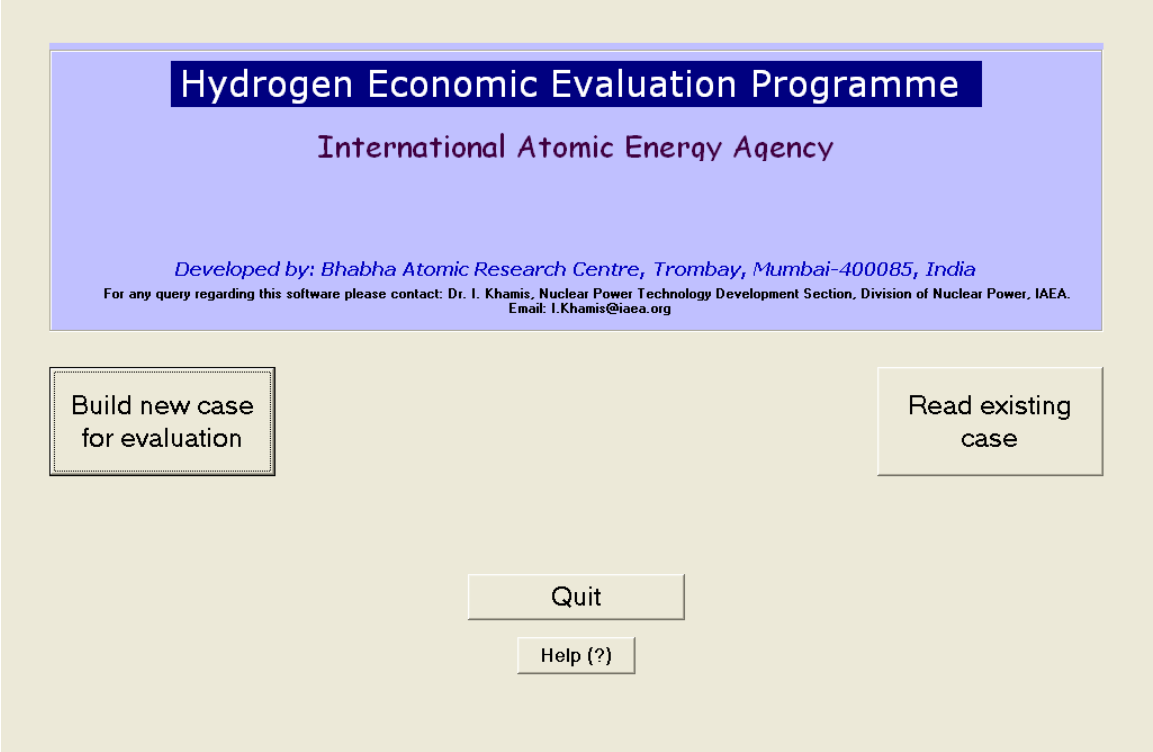


Figure 1-1: Startup screen

The start-up screen gives user two options to proceed further. These options are

(i) Build a new case for evaluation- ***Click 'Build new case for evaluation'***

User has to provide technical details, cost details and time schedules when this option is chosen. This information can either be read from the existing library files or fresh data can be input and a new library file can be generated.

(ii) Read an existing case - ***Click 'Read Existing Case'***

If user has already worked on a case, relevant data/information can be read from the case file. The file is stored in "<*application path*>\DataBase\Cases\". Here application path is the location where "HEEP-PRE.EXE" file is located.

2. General procedures

2.1. Editing procedure:

All the information required for analysis is to be entered in a text box or in cells of a table.

2.1.1. Procedure for individual text boxes:

- ***Click in the text box and insert or edit contents of the text box.***

2.1.2. Procedure for tabular entry:

- ***Click the cell to be edited***
- A text box will appear at cell location along with two buttons "✓" and "X".
- Only active text boxes can be edited. (a cursor " | " appears in the text box when it is active). If the test box is not active then click once in the text box.
- ***Insert/Edit contents of the text box and click "✓" button to effect the changes made***
- ***To discard without effecting any changes, click "X" button***

2.2. Procedure to store data:

Definition of storing data:

Storing the data implies loading it in the working memory. It will remain in memory till execution of programme is not terminated. Once the programme is terminates, user will lose all modifications made.

Click command button starting with the word "Store"

Example: If user wants to store technical details of Nuclear Power Plant then the command button "Store Technical Details of NPP"

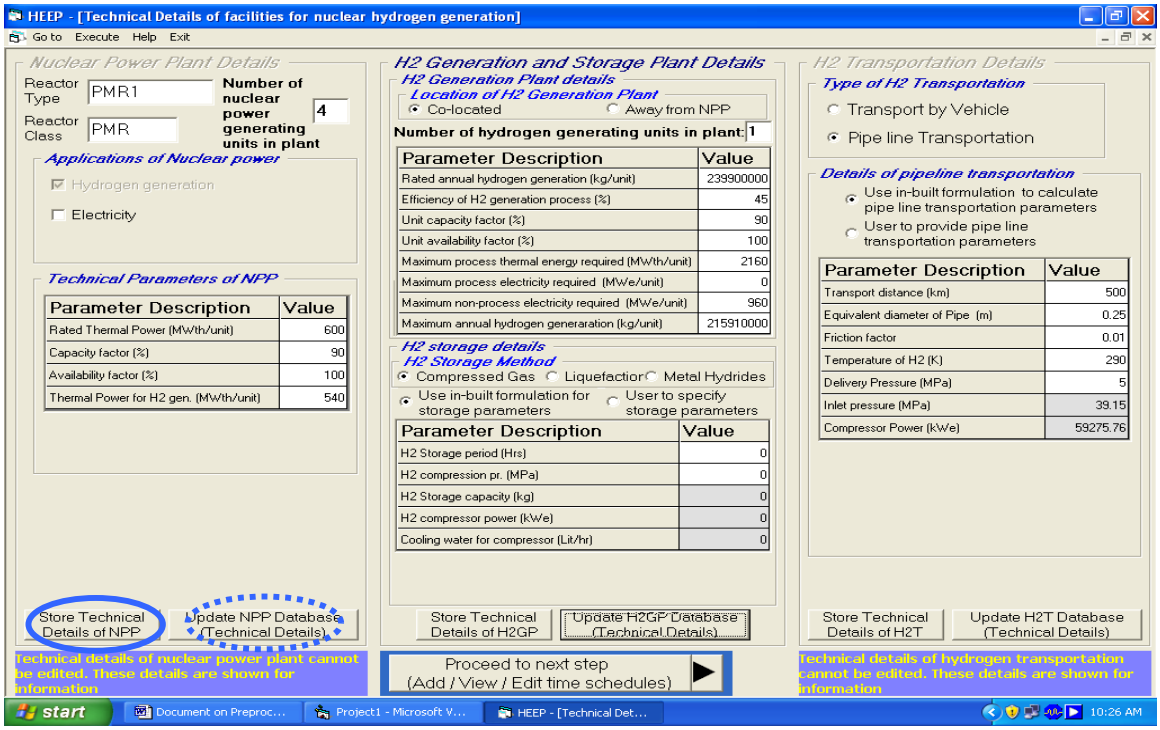


Figure 2-1: Example to show buttons to 'store data' and 'update database'

2.3. Procedure to update database:

Definition of updating database:

Updating database implies storing data in library files. If user terminates the programme and user wants to use modified/edited data once again, it can be retrieved the next time programme is used.

Click command button starting with the word "Update"

Example: If user wants to update technical details of Nuclear Power Plant then the command button "Update NPP "

2.4. General tips:

- As a minimum, always "store" the data before proceeding to next step. Unless data is stored, edited/ modified information will not be effective.
- If user wants to retrieve the data in future, the modified /edited information must be updated in the database by clicking "Update Database" button.

3. Important steps for executing HEEP:

Step	Description of action	Reference section in manual
1	Read data from data base OR Create new data base	4, 4.1, 4.2
2	Enter details of nuclear power plant	
2.1	Enter or Edit Technical Details of nuclear power plant	5.1, 5.1.1
2.2	Enter or Edit Time Schedule for nuclear power plant	5.2
2.3	Enter or Edit General cost details	5.3.1
2.4	Enter or Edit Capital cost details for nuclear power plant	5.3.2, 5.3.2.1, 5.3.2.2, 5.3.2.3
2.5	Enter or Edit cost details for Front End of Fuel Cycle	5.3.3.1
2.6	Enter or Edit cost details for Back End of Fuel Cycle	5.3.3.2
2.7	Enter or Edit cost details for Consumables and locked in inventory for nuclear power plant	5.3.3.3
2.8	Enter or edit Operation and Maintenance (O&M) cost for nuclear power plant	5.3.3.4 5.3.3.4.1 5.3.3.4.2(a)
2.9	Enter or Edit Decommissioning cost details for nuclear power plant	5.3.4, 5.3.4.1, 5.3.4.2.1
3	Enter details of hydrogen generation and storage plant	
3.1	Enter or Edit Technical Details of hydrogen generation plant	5.1, 5.1.2
3.2	Enter or Edit Time Schedule for hydrogen generation plant	5.2
3.3	Enter or Edit General cost details	5.3.1
3.4	Enter or Edit Capital cost details for hydrogen generation plant	5.3.2, 5.3.2.1, 5.3.2.2, 5.3.2.2.1, 5.2.3.2.1(a) to (c), 5.3.2.3
3.5	Enter or Edit cost details for Consumables and locked in inventory for hydrogen generation and storage plant	5.3.3.3
3.6	Enter or edit Operation and Maintenance (O&M) cost for hydrogen generation plant	5.3.3.4, 5.3.3.4.1, 5.3.3.4.2(b)
3.7	Enter or Edit Decommissioning cost details for hydrogen generation and storage plant	5.3.4, 5.3.4.1, 5.3.4.2.2
4	Enter details of hydrogen transportation and distribution facility	
4.1	Enter or Edit Technical Details of hydrogen transportation	5.1, 5.1.3
4.2	Enter or Edit Time Schedule for hydrogen transportation	5.2
4.3	Enter or Edit General cost details	5.3.1
4.4	Enter or Edit Capital cost details for hydrogen transportation	5.3.2, 5.3.2.1, 5.3.2.2, 5.3.2.2.2, 5.2.3.2.2(a) to (b), 5.3.2.4
4.5	Enter or Edit cost details for Consumables and locked in inventory for hydrogen transportation facility	5.3.3.3
4.6	Enter or edit Operation and Maintenance (O&M) cost for hydrogen transportation	5.3.3.4, 5.3.3.4.1, 5.3.3.4.2(c)
4.7	Enter or Edit Decommissioning cost details for hydrogen transportation and distribution facility	5.3.4, 5.3.4.1, 5.3.4.2.2

4. Options of building new case:

User can build a new case for evaluation using two methods:

(a) Reading required information from library files and editing it accordingly.
(b) Building new library file by entering fresh data.

4.1. Reading information from library file

Required information can be read from the library of files in the database. A message box pops up providing the steps to read information from database. A list of available files in the database is provided in the list box highlighted with the 'blue ovals' in the Figure 4-1. Important parameters of the library file are shown in a table after ***selecting library file***. User can decide on using the selected library file or create a new one.

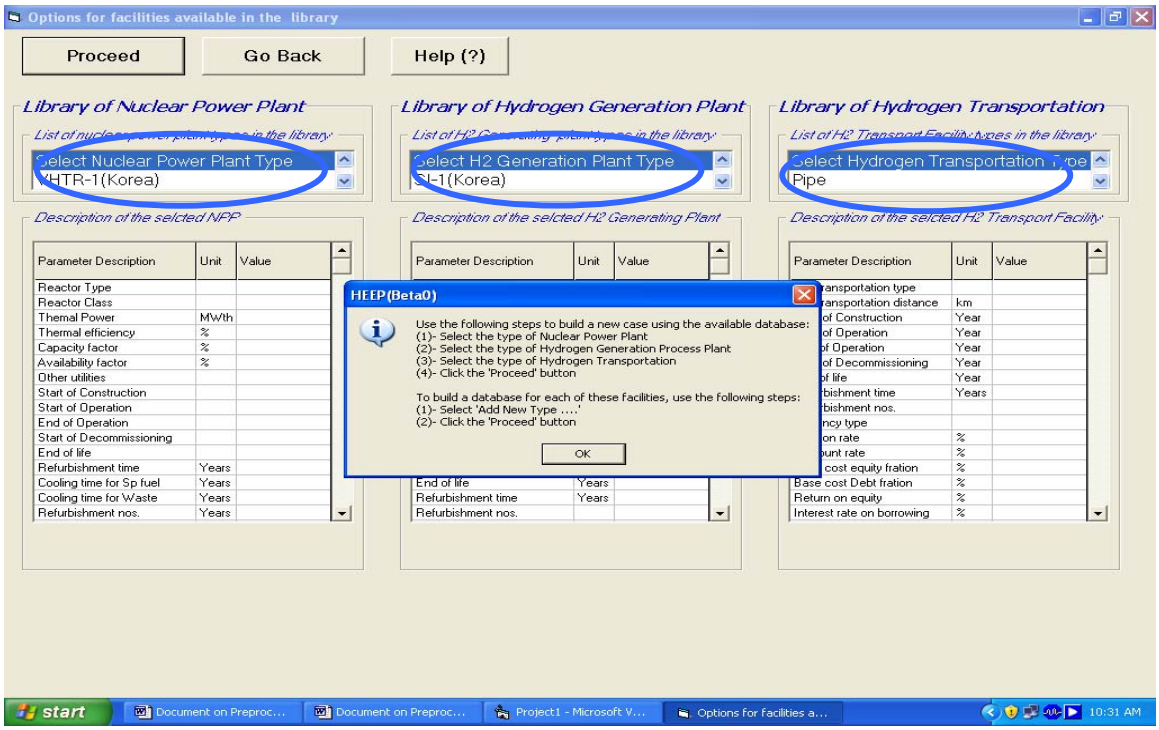


Figure 4-1: Option of building new case by reading information from library files

In the current example, sample library files viz. 'AAA' for nuclear power plant, 'BBB' for hydrogen generation station and 'CCC' for hydrogen transportation facility are selected. In order to choose the file from the available library, information on important parameters is displayed in tabulated manner as described in the Figure 4-2. This would help the user to select the closest case. After selecting library files, "Proceed" button is to be clicked to move to next step.

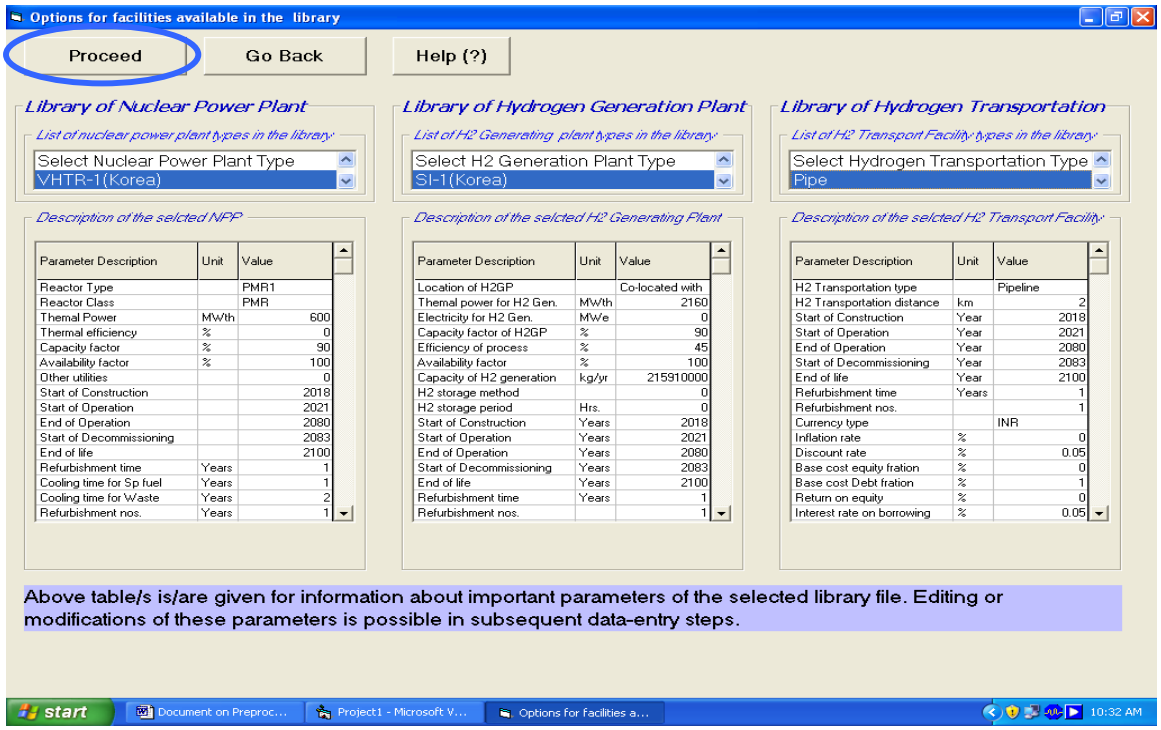


Figure 4-2: Parameters of the selected library file

A flowsheet of main components of nuclear hydrogen generation and distribution is shown in Figure 4-3. Expenditures are shown in black color and revenue components are shown in violet color. Flow of energy forms is shown in green color.

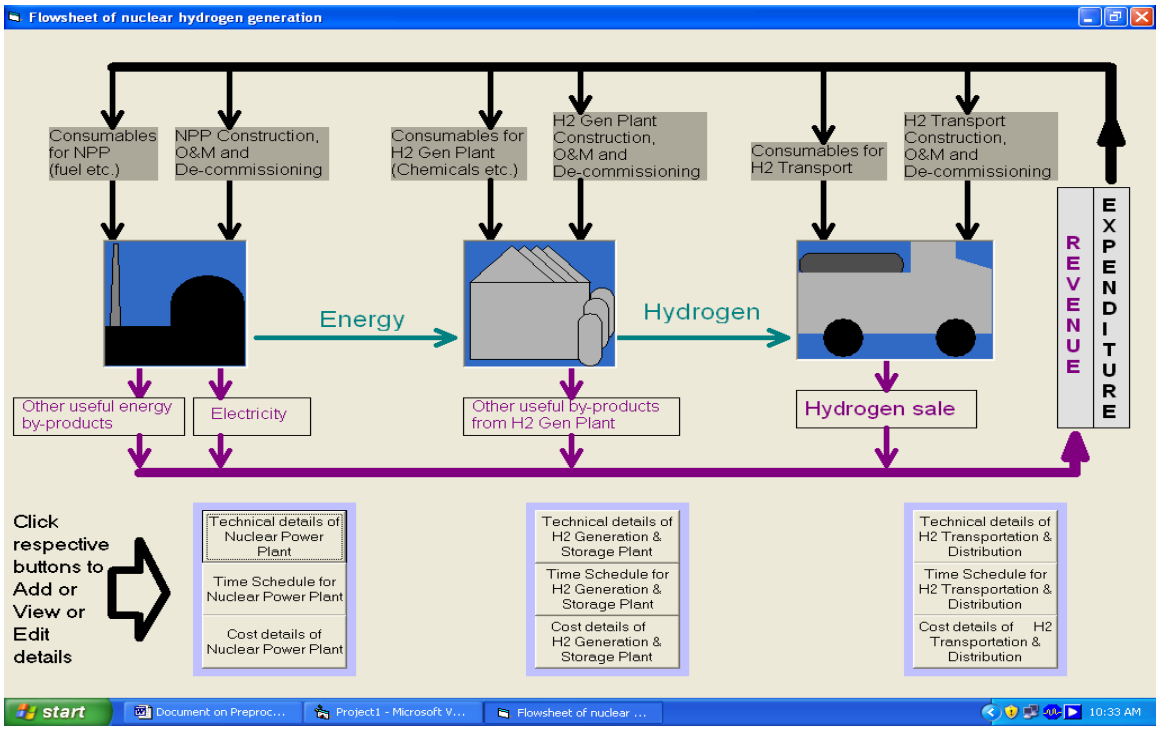


Figure 4-3: Flowsheet showing editable elements when data read from library files

User is required to edit/enter information in specified format for three main components for each plant or facility that affects the economics of nuclear hydrogen generation. These three components are (a) Technical details, (b) Time periods of various events and (c) different cost components. ***Click appropriate button to view or edit the data.***

4.2. Building new library file by entering fresh data

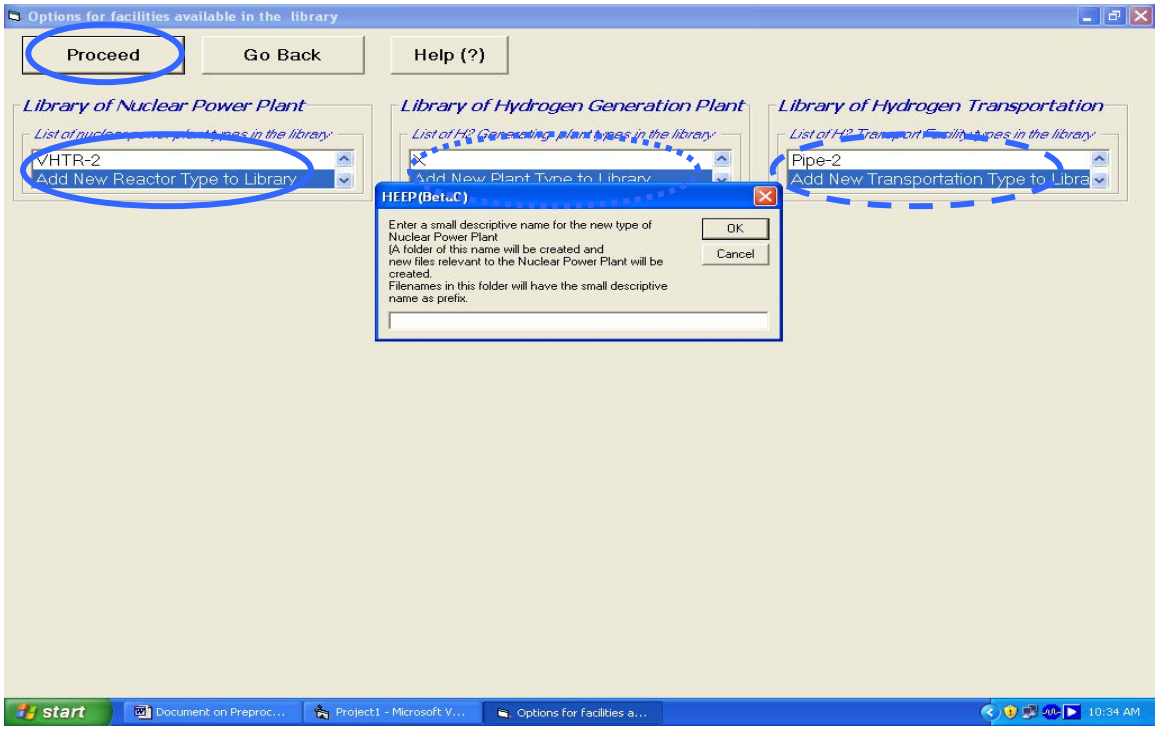


Figure 4-4: Option of building new library file

If the desired system has not yet been saved as a file in the database, user has to create new file for 'Nuclear Power Plant' or 'Hydrogen Generation Station' or 'Hydrogen Transportation'. For creating a new file, user has to ***select "Add new library file to database"*** and then ***click "Proceed" button.*** The programme prompts the user to provide a small descriptive name for the nuclear power plant or hydrogen generation station or hydrogen transportation facility. This small name will form the prefix of the filenames generated and stored after user provides relevant information. An example is shown in the following diagram.

After providing the required cryptic name/s for nuclear power plant or hydrogen generation station or hydrogen transportation facility, **user will be prompted to enter "Technical Data" for nuclear power plant.**

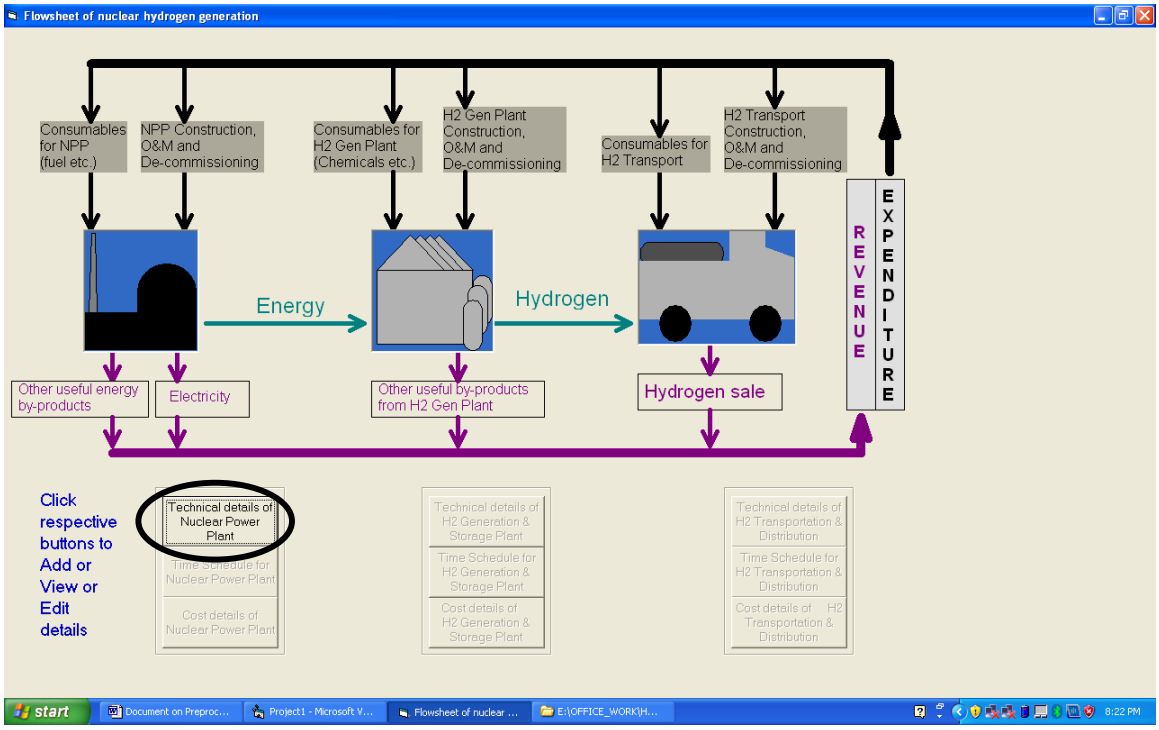


Figure 4-5: Flowsheet showing editable elements when data read from library files

5. Add/view/edit parameters affecting hydrogen generation:

5.1. Technical details:

To add or edit or view technical details of plants and facilities for hydrogen generation:

- ***In the window showing flowsheet click the button 'Technical details of Nuclear Power Plant' or 'Technical details of H2 Generation & Storage Plant' or 'Technical details of H2 Transportation & Distribution'.***

  To go to flowsheet

  - ***From pull down menu click 'Go to' - 'Flowsheet'***

  OR

- ***Click 'Go to' > 'Technical Details' from pull down menu***

The relevant frame (corresponding to nuclear power plant or H2 Generation & Storage Plant or H2 Transportation) will be active and rest will be inactive. In the following Figure 5-1, frame corresponding to nuclear power plant is active and remaining frames are inactive.

Users have to provide relevant technical details in corresponding cells of the tables and click radio buttons to select their options. The procedure for providing data in the table is given in section 2.1.2 of this manual.

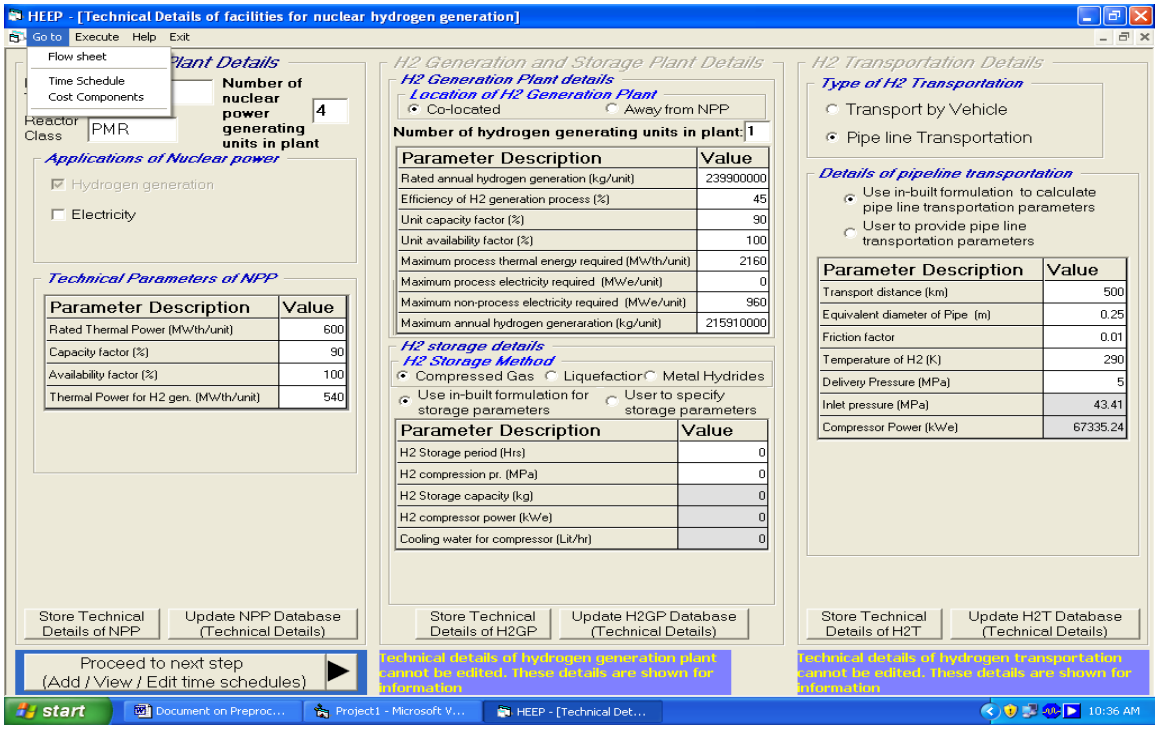


Figure 5-1: Technical details of nuclear power plant, hydrogen generation and storage, and hydrogen transportation

5.1.1. Technical details of Nuclear Power Plant

Click 'Go to' > 'Technical Details' from pull down menu (If user is entering details relevant to nuclear power plant)

OR

Click "Go to" > "Flowsheet" from pull down menu followed by clicking the button "Technical Details of Nuclear Power Plant" on screen showing flow-sheet

User has to provide following technical details of nuclear power plants in the text boxes:

- **Reactor Type** e.g. HTR for High Temperature Reactor, LMR for Liquid Metal Cooled reactor, GCR for Gas Cooled Reactor etc.
- **Reactor Class** e.g. PBR for Pebble bed type, PMR for Prismatic core type, LCR for Lead cooled reactor etc.

It may be noted that the above details are required for information only and does not contribute to cost calculation of nuclear hydrogen generation.

- Number of units generating nuclear power in a plant

Apart from hydrogen generation, if nuclear power plant generates electricity then ***click the check box corresponding to "Electricity" under "Other application of NPP"*** before entering other parameters listed in the Table 5-1 (Refer Figure 5-1). If the check box is clicked at later time, it is likely that all entered parameters may be reset to '0'.

Table 5-1: Technical details of Nuclear Power Plant

Sl.	Parameter	Unit	Variable name
1	Rated thermal Power from one unit of nuclear plant	MWth	Power_Th
2	Thermal efficiency to produce electricity	%	Efficiency
3	Total Electric Power generated by one unit	Mwe	Power_E
4	Unit capacity factor of nuclear power plant	%	CapFactor_NPP
6	Unit availability factor of nuclear power plant	%	AvailFactor_NPP
7	Thermal Power available from one unit for Hydrogen Generation	MWth	PowerThforH2Gen

If thermal power available per unit of nuclear power plant for hydrogen generation is more than the maximum thermal capacity of that unit then, programme will reduce the value of thermal power for hydrogen generation to maximum quantity of thermal power generated by single unit of nuclear power plant.

The maximum amount of thermal energy generated by nuclear power plant is calculated using the formula: $Thermalpower\_NPP = Power\_Th * \frac{CapFactor\_NPP}{100}$

If user selects electricity generation as another application, the net electricity generated is calculated using: $Power\_E = (Power\_Th - PowerThforH2Gen) * Efficiency\_NPP$

5.1.1.1. Next step after providing technical details for nuclear power plant

Click the button "Proceed to next step (Add / View / Edit Time schedules)" to enter various milestones of nuclear power plants and time periods. (Refer Figure 5-1)

5.1.2. Technical details of Hydrogen Generation and Storage Plant

Click 'Go to' > 'Technical Details' from pull down menu (If user is entering details relevant to hydrogen generation and storage plant)

OR

Click "Go to" > "Flowsheet" from pull down menu followed by clicking the button "Technical Details of Hydrogen Generation and Storage Plant" on screen showing flow-sheet

5.1.2.1. Technical details of Hydrogen Generation Unit

Even though the programme has been developed for estimation of cost of nuclear hydrogen generation, user can select the location of hydrogen generation plant from two options.

(a) Co-located plant- in this option the thermal energy and electricity (if generated) is obtained from the nuclear power plant.
(b) Away from NPP- in this option thermal energy and electricity are taken from grid. (Since the programme has been developed for estimation of cost of nuclear hydrogen generation, it is considered that NPP is providing energy for hydrogen generation)

The location of hydrogen generation plant can be selected by ***clicking Option button for 'Co-located with NPP' or 'Away from NPP'.***

If user selects option (a), the programme internally checks total energy balance. If total electricity required for hydrogen generation and transportation exceeds net electricity generated by nuclear power plant, programme assumes that the excess electricity will be obtained from the grid.

User has to ***enter number of hydrogen generating units*** in the text box provided to enter this information.

Apart from this, user has to provide following information in the cells of the table.

Table 5-2: Technical details of Hydrogen Generation and Storage Plant

Sl.	Parameter	Unit	Variable name
1	Rated annual hydrogen generation	Kg/unit	H2GenCap
3	Efficiency of hydrogen generation process	%	Efficiency_H2GP
4	Unit capacity factor	%	CapFactor_H2GP
5	Unit availability	%	AvailFactor_H2GP
6	Max. process thermal power required by each unit	MWth	PowerTh_H2GP
7	Max. process electricity required by each unit	MWe	PowerEforH2Gen
	Non-process electricity required by each unit	Mwe	PowerE_NonProcess

The programme checks for energy balance. The maximum level of thermal power required by each unit is determined using following formula:

$$PowerTh\_H2GP = \frac{H2GenCap * \frac{CapFactor\_H2GP * AvailFactorH2GP}{100*100} * 142.0}{3600*8760*Efficiency\_h2GP} - \frac{PowerEforH2GP}{0.4}$$

In this formula it is assumed that the calorific value of hydrogen is 142 and, the thermal efficiency to generate electricity is 40%.

If user has entered maximum process thermal power (PowerTh_H2GP) less than maximum level of thermal power required by each unit (PthHPMax) to generate maximum amount of hydrogen (depending on unit capacity and availability factor as well as the rated annual hydrogen generation capcity), then programme will change the value of maximum process thermal power to maximum level of thermal power. The programme also checks if all units of nuclear power plant can deliver thermal power required for desired level of hydrogen generation by all units of hydrogen generation. If all units of nuclear power plants are generating less thermal power, the programme prompts user to check technical data. In such case user can change one or more parameters from following list:

a. Rated annual hydrogen generation of each unit
b. Rate power generation by each unit of nuclear power plant
c. Efficiency of hydrogen generation process
d. Unit capacity and/or availability factors of nuclear power plant and/or hydrogen generation station
e. Maximum process electricity

5.1.2.2. Technical details of Hydrogen Storage Unit

Three storage options are available for hydrogen storage.

(a) Gaseous storage
(b) Liquid storage
(c) Metal hydride storage

User can opt from one of three options by clicking the appropriate Option Button provided for type of hydrogen storage.

5.1.2.2.1. Technical details of gaseous storage of hydrogen

Table 5-3 gives a list of the technical parameters concerning gaseous storage

Table 5-3: Technical parameters affecting cost of hydrogen for storage of hydrogen in gaseous form

Sl.	Parameter	Unit	Variable name
1	Storage pressure	MPa	H2ComPr
2	Hydrogen storage capacity	kg	H2StoreCap
3	Hydrogen storage compressor power	kWe	H2ComPower
4	Cooling water requirement for compressor	Lit/hr	H2CoolWater

User can enter these parameters as user specific parameters. However, programme can calculate these parameters if user provides input for Hydrogen Storage period (variable name- H2StoreTime) in hours. ***To use this option, click radio button "Use in-built formulation for storage parameters".***

Formula used for calculation of storage capacity is:

$$H2StoreCap = \frac{H2StoreTime * H2GenCap}{8760}$$

Formula for calculation of compressor power is:

$$H2ComPower = H2GenCap * NStages * \left(\frac{\gamma}{\gamma - 1}\right) * R * T * \left(\frac{H2Com\,\mathrm{Pr}}{Gen\,\mathrm{Pr}}\right)^{\left(\frac{\gamma-1}{NStages*\lambda}-1\right)}$$

Where,

γ = Adiabatic index (1.4)
R = Gas constant (4124 J/kg.K)
T = Temperature (290 K)
GenPr = Hydrogen generation pressure (assumed to be atmospheric pressure)
Nstages = Number of stage of compressor

1 if H2ComPr < 0.5 Mpa
2 if 0.5 Mpa < H2ComPr < 5 Mpa
3 if H2ComPr > 5 Mpa

Formula used for calculation of cooling water requirement for compressor is [1]:

$$H2CoolWater = \frac{H2ComPower * 50}{2.2}$$

5.1.2.2.2. Technical details of storage of hydrogen in liquid form

Table 5-4 gives technical parameters related to hydrogen storage in liquid form affecting total cost of hydrogen.

Table 5-4: Technical parameters affecting hydrogen cost storage of hydrogen in liquid form

Sl.	Parameter	Unit	Variable name
1	Hydrogen storage capacity	kg	H2StoreCap
2	Hydrogen storage liquefaction power	kWe	H2LiqPower
3	Cooling water requirement for liquefaction	Lit/hr	H2CoolWater

User can enter these parameters as user specific parameters. However, programme can calculate these parameters if user provides input given in Table 5-5. ***To use this option, click radio button "Use in-built formulation for storage parameters".***

Table 5-5: Technical inputs required for calculation of parameters of hydrogen storage in liquid form affecting cost of hydrogen

Sl.	Parameter	Unit	Variable name
1	Hydrogen storage period	Hours	H2StoreTime
2	Hydrogen storage liquefaction energy	KWh/kg of H2	H2LiqEnergy
3	Cooling water requirement for liquefaction	Lit/kg of H2	H2CoolWaterR
4	Boil off rate	%/day	H2BOR

The storage capacity is calculated using the following formula:

$$H2StoreCap = H2StoreTime * \frac{H2GenCap}{8760}$$

Formula for calculation of liquefaction power is[1]:

$$H2LiqPower = H2LiqEnergy * \frac{H2GenCap}{8760} * \left(1 + \left(1 - e^{\frac{-H2BOR * H2StoreTime}{24*100}}\right)\right)$$

Formula used for calculation of cooling water requirement for liquefaction is[1]:

$$H2CoolWater = \frac{H2GenCap}{8760} * \left(1 + \left(1 - e^{\frac{-H2BOR * H2StoreTime}{24*100}}\right)\right) * H2CoolWaterR$$

5.1.2.2.3. Technical details of storage of hydrogen in the form of metal hydrides

Table 5-6 gives a list of the technical parameters when hydrogen is proposed to be stored in the hydride form.

Table 5-6: Technical parameters affecting hydrogen cost for hydride storage

Sl.	Parameter	Unit	Variable name
1	Hydride Storage capacity	kg	H2StoreCap
2	Hydride storage cooling water	Lit/hr	H2CoolWater
3	Hydride storage heating power	kWheat	HydHeatPower

User can enter these parameters as user specific parameters. However, programme can also calculate these parameters, if user provides input given in Table 5-7.

To use this option click radio button "Use in-built formulation for storage parameters".

Table 5-7: Technical inputs required for calculation of parameters affecting cost of hydrogen when stored in hydride form

Sl.	Parameter	Unit	Variable name
1	Hydride Storage period	Hours	H2StoreTime
2	Hydride Cooling	Lit/kg of H2	H2CoolWaterR
3	Hydride heating	kJ/kg of H2	HydHeatEne

The storage capacity is calculated using following formula is:

$$H2StoreCap = H2StoreTime * \frac{H2StoreCap}{8760}$$

Formula used for calculation of cooling water requirement for hydride formation is [1]:

$$H2CoolWater = H2StoreCap * H2CoolWaterR$$

Formula used for calculation of thermal energy requirement for conversion of hydrogen from hydrides is [1]:

$$HydHeatPower = H2StoreCap * HydHeatEne$$

5.1.2.3. Next step after providing technical details for hydrogen generation and storage facility

Click the button "Proceed to next step (Add / View / Edit Time schedules)" to enter various milestones of hydrogen generation and storage plants and time periods.

5.1.3. Technical details of Hydrogen Transportation

Click 'Go to' > 'Technical Details' from pull down menu (If user is entering details relevant to hydrogen transportation facility)

OR

Click "Go to" > "Flowsheet" from pull down menu followed by clicking the button "Technical Details of Hydrogen Transportation and Distribution" on screen showing flow-sheet

User can select transportation of hydrogen from following two options:

(a) Pipeline transportation
(b) Transportation in a vehicle

User can opt from one of the two options by clicking the appropriate Option Button provided for type of hydrogen transportation.

5.1.3.1. Technical details of Hydrogen Transportation through pipeline

Table 5-8 gives technical parameters of transportation of hydrogen through pipeline.

Table 5-8: Technical inputs required for calculation of parameters affecting cost of hydrogen when stored in hydride form

Sl.	Parameter	Unit	Variable name
1	Transportation distance	m	H2TransDist
2	Equivalent diameter of pipeline	m	H2PipeDia
3	Supply pressure	MPa	H2TransPres
4	Compressor power for transportation	kWe	H2TranPower

User can enter these parameters as user specific parameters. However, programme can also calculate supply pressure and compressor capacity for generating this supply pressure, if user provides additional inputs listed in Table 5-9.

To use this option, click radio button "Use in-built formulation to calculate pipeline transportation parameters".

Table 5-9: Technical inputs required for calculation of parameters affecting cost of hydrogen when stored in hydride form

Sl.	Parameter	Unit	Variable name
1	Transportation temperature	K	H2TransTemp
2	Delivery pressure	MPa	H2TransPrDel
3	Friction factor		H2FricFact

Following formula is used for calculation of supply pressure at hydrogen production and storage end [1]

$$H2Trans\,\mathrm{Pr}es = \sqrt{\frac{4*H2FricFact*H2TransDist*Flux^2*R*H2TransTemp}{H2PipeDia} + H2Trans\,\mathrm{Pr}Del^2}$$

Where,

R = Gas constant (4124 J/kg.K) and $flux = \dfrac{\dfrac{H2GenCap}{3600*8760}}{\dfrac{\Pi}{4}*H2PipeDia^2}$

Following formula is used for calculation of capacity compressor required for hydrogen transportation [1]

$$H2TransPower = H2GenCap*NStages*\left(\frac{\gamma}{\gamma-1}\right)*R*T*\left(\frac{H2Trans\,\mathrm{Pr}es}{Atm\,\mathrm{Pr}}\right)^{\left(\frac{\gamma-1}{NStages*\lambda}-1\right)}$$

Where, *Atm*Pr is atmospheric pressure.

5.1.3.2. Technical details for vehicular transportation of hydrogen

User is required to provide technical parameters listed in Table 5-10 related to transportation of hydrogen in vehicles.

Table 5-10: Technical parameters affecting cost of hydrogen transported in vehicles

Sl.	Parameter	Unit	Variable name
1	Transportation distance	m	H2TransDist
2	Capacity of vehicle	kg	TransVehSpeed
3	Mileage of vehicle	Km/lit of fuel	TransVehMilage
4	Loading time per vehicle	Hours	TransVehLoadTime

5.1.3.3. Next step after providing technical details for hydrogen generation and storage facility

Click the button "Proceed to next step (Add / View / Edit Time schedules)" to enter various milestones and time periods of hydrogen transportation and distribution.

5.2. Time schedules of various events of plants and facilities for nuclear hydrogen generation:

The next step is to enter time schedule for various events of plants and facilities for generation of nuclear hydrogen.

User can open the form for entering time periods using one of the following steps:

Click the button 'Proceed to next step (Add / View / Edit time schedules)' if user has completed the activity of providing technical details.

OR

In the window showing flowsheet click the button 'Time schedule for Nuclear Power Plant' or 'Time schedule for H2 Generation & Storage Plant' or 'Time schedule for H2 Transportation & Distribution'

To go to flowsheet

- ***From pull down menu click 'Go to' - 'Flowsheet'***

OR

Click 'Go to' > 'Time Schedules' from pull down menu

Figure 5-2 shows general layout for entering time schedule details.

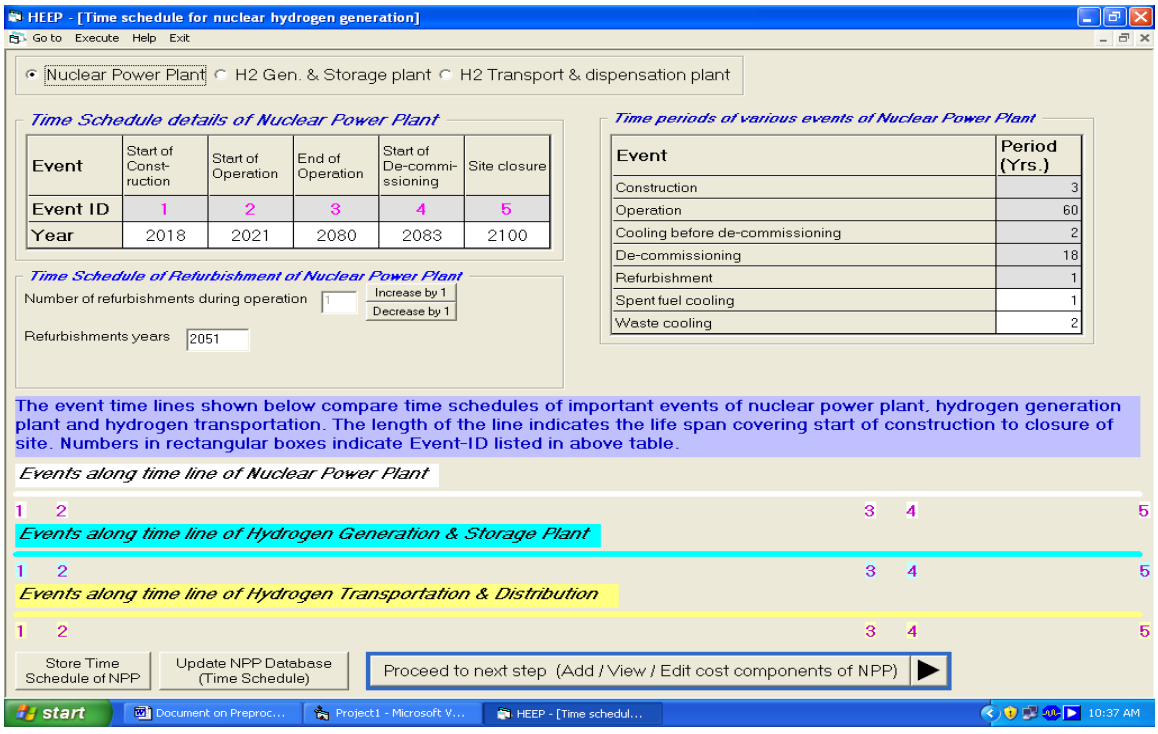


Figure 5-2: Time schedule of important events during nuclear power plant life time

To view or edit details of time schedule for specific plant or facility viz. nuclear power plant, hydrogen generation and storage plant and hydrogen transportation, ***click the specific radio button of corresponding plant.***

Table 5-11 lists the important events in the life of plants and facilities.

Table 5-11: Time schedules of various important events of plants and facilities for nuclear hydrogen generation

Sl.	Parameter	Unit	Variable name
Time schedule of important events of Nuclear power plant			
1	Start of construction	Calendar year	Y_ConsStart_NPP
2	Start of operation		Y_OpStart_NPP
3	End of operation		Y_OpEnd_NPP
4	Start of decommissioning		Y_DecomStart_NPP
5	Site closure		Y_SiteClose_NPP
Time schedule of important events of Hydrogen generation plant			
6	Start of construction	Calendar year	Y_ConsStart_H2GP
7	Start of operation		Y_OpStart_H2GP
8	End of operation		Y_OpEnd_H2GP
9	Start of decommissioning		Y_DecomStart_H2GP
10	Site closure		Y_SiteClose_H2GP
Time schedule of important events of facility for hydrogen transportation and distribution			
11	Start of construction	Calendar year	Y_ConsStart_H2T
12	Start of operation		Y_OpStart_H2T
13	End of operation		Y_OpEnd_H2T
14	Start of decommissioning		Y_DecomStart_H2T
15	Site closure		Y_SiteClose_H2T

All these details have to be provided in terms of calendar year e.g. 2009, 2010, 2026 etc.

Based on the above input, the programme calculates time periods of important activities of plants and facilities for nuclear hydrogen generation. The formulae for these time periods are listed in Table 5-12.

Table 5-12: Time periods of various activities of plants and facilities for nuclear hydrogen generation (calculated by the programme)

Sl.	Parameter	Formula used	Variable name
Time period of important events of nuclear power plant			
1	Construction period	Y_OpStart_NPP - Y_ConsStart_NPP	N_Const_NPP
2	Operating period	Y_OpEnd_NPP - Y_OpStart_NPP + 1	N_Op_NPP
3	Cooling period before decommissioning	Y_DecomStart_NPP - Y_OpEnd_NPP - 1	N_Cool_NPP
4	Decommissioning period	Y_SiteClose_NPP - Y_DecomStart_NPP + 1	N_Decom_NPP

Sl.	Parameter	Formula used	Variable name
Time period of important eventsof hydrogen generation plant			
5	Construction period	Y_OpStart_H2GP - Y_ConsStart_H2GP	N_Const_H2GP
6	Operating period	Y_OpEnd_H2GP - Y_OpStart_H2GP + 1	N_Op_H2GP
7	Cooling period before decommissioning	Y_DecomStart_H2GP - Y_OpEnd_H2GP - 1	N_Cool_H2GP
8	Decommissioning period	Y_SiteClose_H2GP - Y_DecomStart_H2GP + 1	N_Decom_H2GP
Time period of important events of facilities for hydrogen transportation and distribution			
9	Construction period	Y_OpStart_H2T - Y_ConsStart_H2T	N_Const_H2T
10	Operating period	Y_OpEnd_H2T - Y_OpStart_H2T + 1	N_Op_H2T
11	Cooling period before decommissioning	Y_DecomStart_H2T - Y_OpEnd_H2T - 1	N_Cool_H2T
12	Decommissioning period	Y_SiteClose_H2T - Y_DecomStart_H2T + 1	N_Decom_H2T

In addition to the above, the user has to provide information regarding time period of some other important activities of these plants and facilities as listed in Table 5-13.

Table 5-13: Additional information regarding time period of other important activities of plants and facilities for nuclear hydrogen generation

Sl.	Parameter	Unit	Variable name
Time schedule of some other important events of Nuclear power plant			
1	Refurbishment period	years	N_Refur_NPP
2	Spent fuel cooling period	years	N_SpFuelCool_NPP
3	Waste cooling period	years	N_HLWCool_NPP
Time schedule of some other important events of Hydrogen generation plant			
4	Refurbishment period	years	N_Refur_H2GP
Time schedule of some other important events of facility for hydrogen transportation and distribution			
5	Refurbishment period	years	N_Refur_H2T

Note: In the present version the refurbishment period is taken as 1 calendar year

Apart from this, user has to provide number of refurbishments and calendar years for refurbishments of each plant or facility during their operation.

Number of refurbishments can be increased or decreased by clicking the button 'Increase by 1' or 'Decrease by 1'. Calendar years of refurbishments can be provided in respective text boxes.

5.2.1. Next step after providing technical details for hydrogen generation and storage facility

Click the button "Proceed to next step (Add / View / Edit Cost Components of NPP or H2GP or H2T)" to enter various cost components of nuclear power plant or hydrogen generation and storage plant or hydrogen transportation. (Refer Figure 5-2)

- *If user is entering time schedules for nuclear power plant, command button with label "Proceed to next step (Add / View / Edit Cost Components of NPP)" will appear.*
- *If user is entering time schedules for hydrogen generation and storage plant, command button with label "Proceed to next step (Add / View / Edit Cost Components of H2GP)" will appear.*
- *If user is entering time schedules for hydrogen transportation, command button with label "Proceed to next step (Add / View / Edit Cost Components of H2T)" will appear.*

5.3. Cost components of plants and facilities for nuclear hydrogen generation:

The next step is to enter the cost for various components of plants and facilities for generation of nuclear hydrogen.

5.3.1. General economics details

User can open form/window for entering cost components of nuclear power plant or hydrogen generation plant or hydrogen transportation using one of the following steps:

Click the button 'Proceed to next step (Add / View / Edit Cost Components of NPP or H2GP or H2T)' if user has completed entering time schedules for the nuclear power plant or hydrogen generation plant or hydrogen transportation.

OR

In the window showing flowsheet click the button "Cost Details of Nuclear Power Plant" or "Cost Details of H2 Generation & Storage Plant" or "Cost Details of H2 Transportation & Distribution"

To go to flowsheet

- ***From pull down menu click 'Go to' - 'Flowsheet'***

OR

Click 'Go to' – 'Cost Components' from pull down menu

Figure 5-3, Figure 5-4 and Figure 5-5 show the forms indicating different cost components of nuclear power plant, hydrogen generation and storage plant and hydrogen transportation respectively.

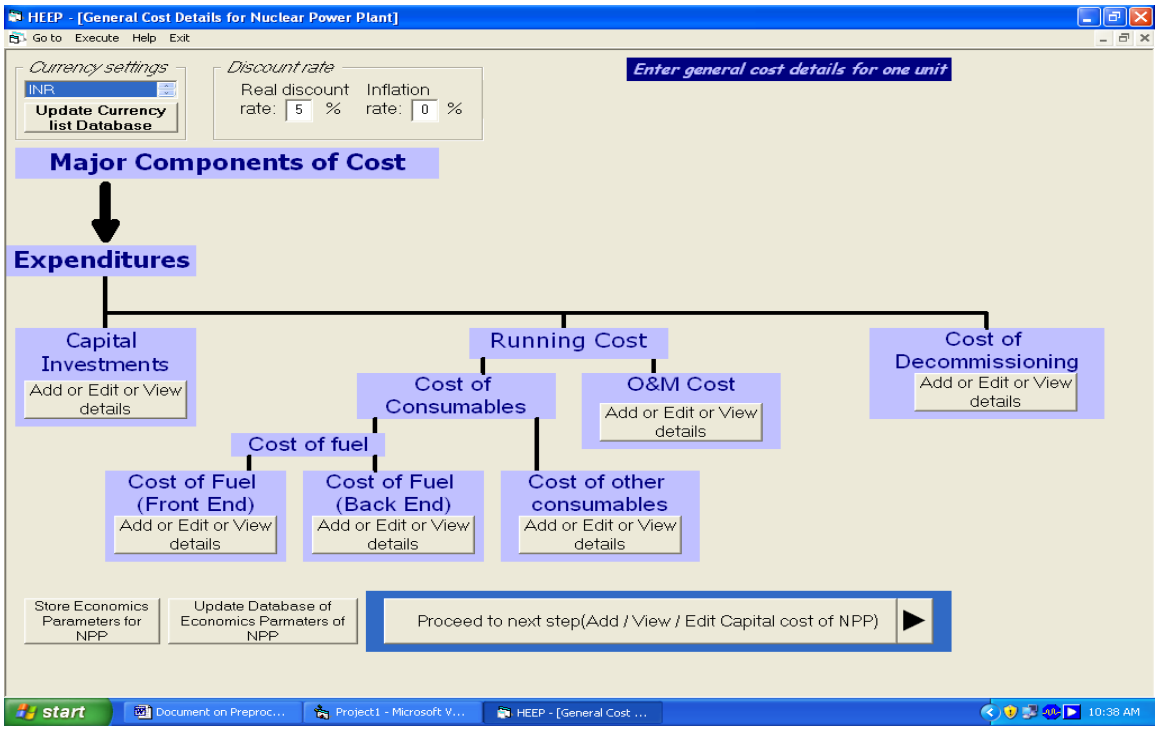


Figure 5-3: Cost components of nuclear power plant

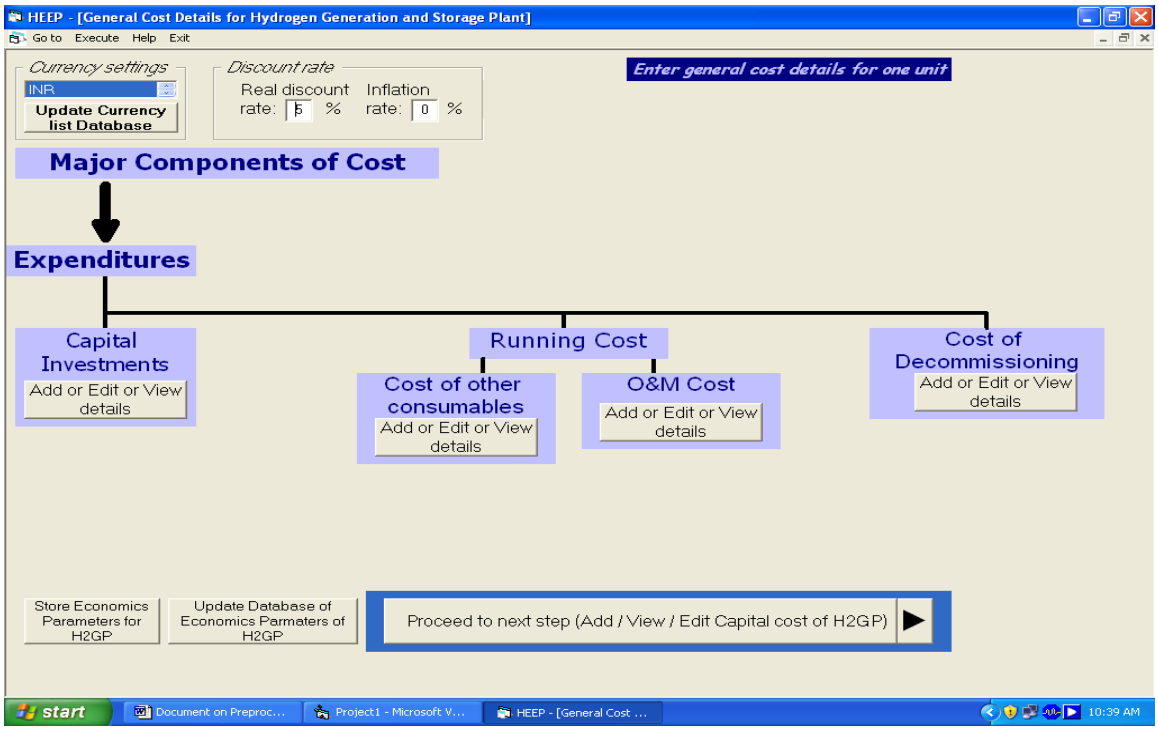


Figure 5-4: Cost components of hydrogen generation and storage plant

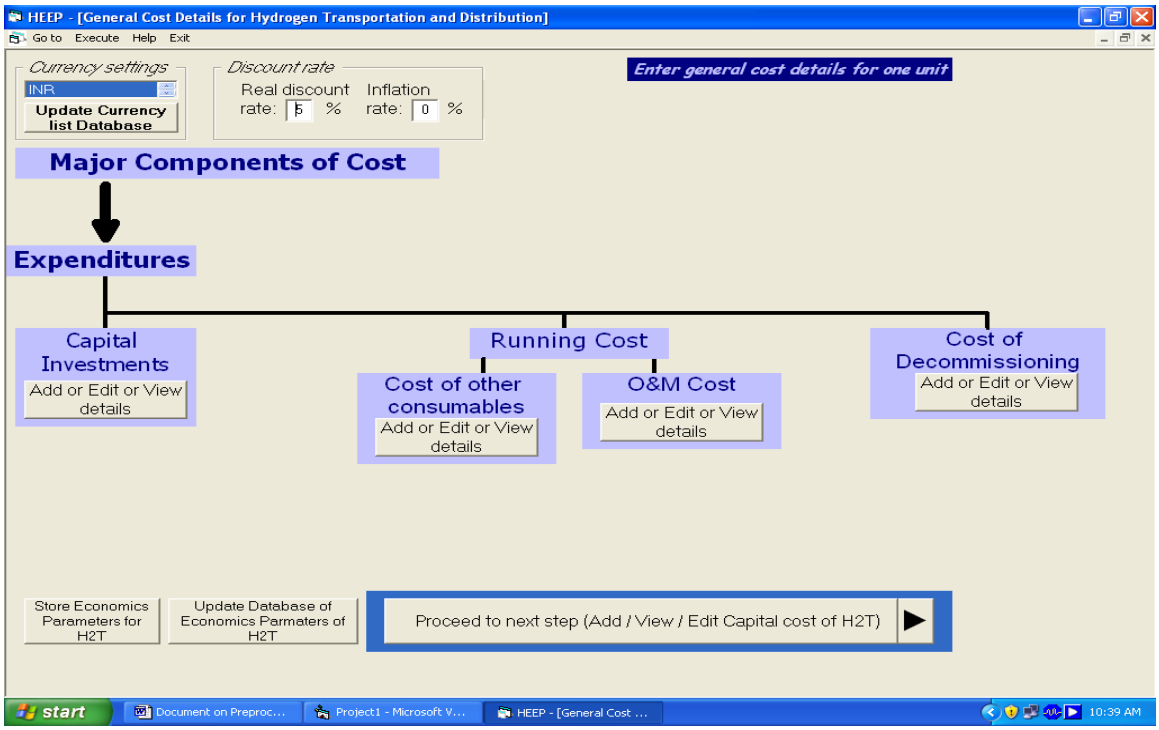


Figure 5-5: Cost components of hydrogen transportation

Before providing the details of the cost, user has to Add / Edit / View general cost components as listed in Table 5-14.

Table 5-14: General cost components affecting cost of hydrogen generation

Sl.	Parameter	Unit	Variable name
1	Currency used in the analysis		Cur
2	Real discount rate	%	DiscR_R
3	Inflation rate	%	InflR

User can select the type of currency from the available list. If the currency type is not included in the list, user can create his own currency using steps indicated below. However, note that currency should be kept consistent throughout the analysis.

Steps to create new currency type

(a) Click on "ADD NEW Currency"
(b) Enter type of new currency in the popped up text box
(c) Click "OK" to add the new currency type in the list box.
(d) ***Click "Update currency list database"***

If user changes the currency type, care must be taken to convert all cost figures corresponding to the selected currency type

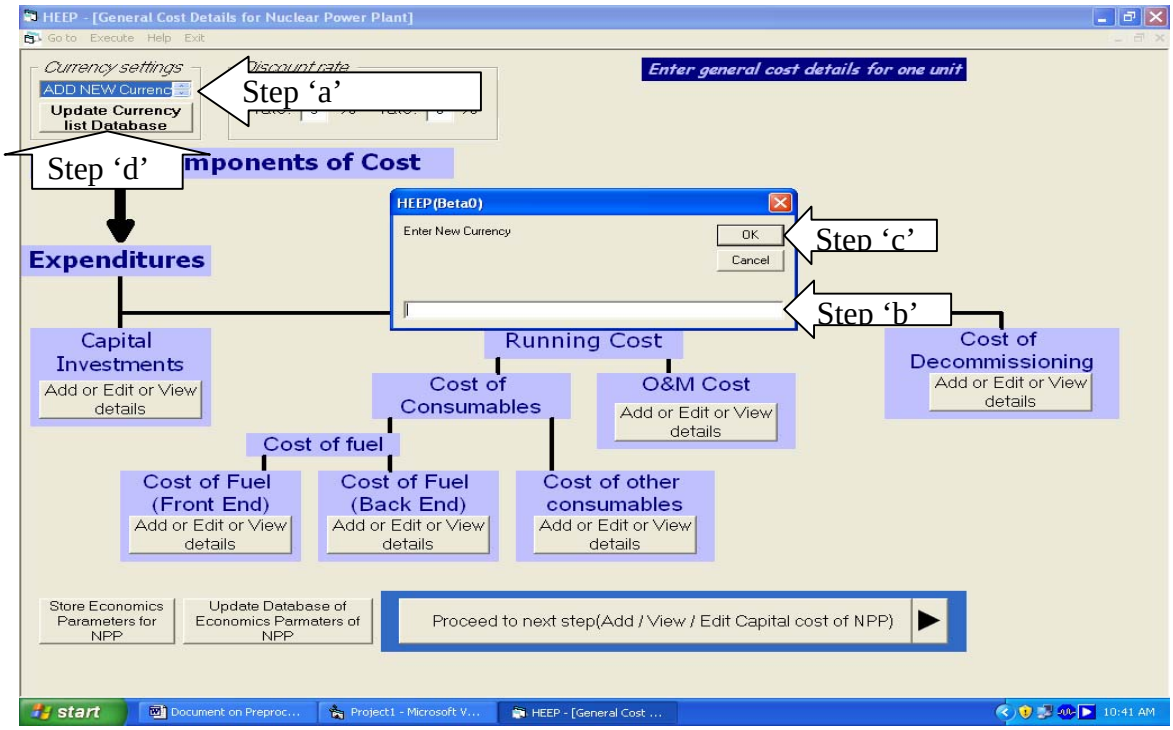


Figure 5-6: Cost components of hydrogen transportation

Details provided in this form are common to all the three plants i.e. nuclear power plant, hydrogen generation plant and hydrogen transportation.

5.3.1.1. Next step after providing general economics details

Table 5-15 gives a list of the major cost components of a plant, in general. Specific costs are denoted in the table via '✓' and 'X' in each column.

Table 5-15: Major cost components of different plants and facilities affecting cost of nuclear hydrogen generation

Sl.		Cost Component	Applicability for type of plant or facility		
			Nuclear power plant	Hydrogen generation and storage plant	Hydrogen transportation and distribution
1		Capital Cost	✓	✓	✓
2		Running cost	✓	✓	✓
	2.1	Cost of fuel cycle (front end)	✓	X	X
	2.2	Cost of fuel cycle (back end)	✓	X	X
	2.3	Cost of consumables	✓	✓	✓
	2.4	O&M cost	✓	✓	✓
3		Decommissioning cost	✓	✓	✓

Click the button 'Proceed to next step (Add / View / Edit Capital cost of NPP or H2GP or H2T)' if user has completed entering general parameters for the nuclear power plant or hydrogen generation plant or hydrogen transportation. (This will open window / form for viewing or editing or adding components of capital cost for relevant plant or facility).

5.3.2. Capital cost details

The next step is to enter details of capital investments for plants and facilities for generation of nuclear hydrogen.

User can open the form for entering details of capital investments of nuclear power plant or hydrogen generation plant or hydrogen transportation using any one of the following steps:

Click the button 'Proceed to next step (Add / View / Edit Capital Cost of NPP or H2GP or H2T)' if user has completed entering general cost components for the nuclear power plant or hydrogen generation plant or hydrogen transportation.

OR

In the window showing flowsheet click the button 'Cost Components of Nuclear Power Plant' or 'Cost Components of H2 Generation & Storage Plant' or 'Cost Components of H2 Transportation & Distribution' OR Click 'Go to' – 'Cost Components' from pull down menu
Click "Add or Edit or View details" of Capital investments

To go to flowsheet

- ***From pull down menu click 'Go to' - 'Flowsheet'***

User has to provide following finance details given in Table 5-16.

Table 5-16: Finance options

Sl	Parameter	Unit	Variable names for		
			Nuclear power Plant	Hydrogen generating plant	Hydrogen transportation
1	Equity fraction	%	Eqt_NPP	Eqt_H2GP	Eqt_H2T
2	Debt fraction[1]	%	Dbt_NPP	Dbt_H2GP	Dbt_H2T
3	Return on Equity	%	ROE_NPP	ROE_H2GP	ROE_H2T
4	Interest on borrowing	%	BorrowInt_NPP	BorrowInt_H2GP	BorrowInt_H2T
5	Return period for borrowing	Yrs	BorrowretYrs_NPP	BorrowretYrs_H2GP	BorrowretYrs_H2T

[1] Automatically linked to the equity fraction

User has two options for providing capital cost.

(a) Option in which programme will calculate total capital cost (base cost) of the facility based on the information provided by user as described in the Table 5-17.
(b) Providing component level details

In case of nuclear power plant click appropriate option button from the two options "Use Specific Cost (Cost of unit capacity)" or "Use Component level details"

In case of hydrogen generation storage plant or hydrogen transportation click appropriate option button from the two options "Use in-built formulation for total base cost calculation" or "Use Component level details"

5.3.2.1. Providing component level details to calculate capital cost

Component level details can be provided in two levels. User has to create "main heads" of capital cost and provide cost of all "minor head" of the each "main head". It may be noted that user cannot directly enter cost of main head. It is essential to create at least one minor head.

Follow the steps given below to provide component level details

- Step-1: When user selects to provide component level details command button "View/Edit Base Cost Component" will be visible.

Click command button "View/Edit Base Cost Component" to view/edit/add main heads

(Refer screenshots shown on subsequent pages)

- Step-2: Frame showing details of main head already provided will be visible. If user is entering main heads for the first time, the table showing main head details and their cost will be blank.

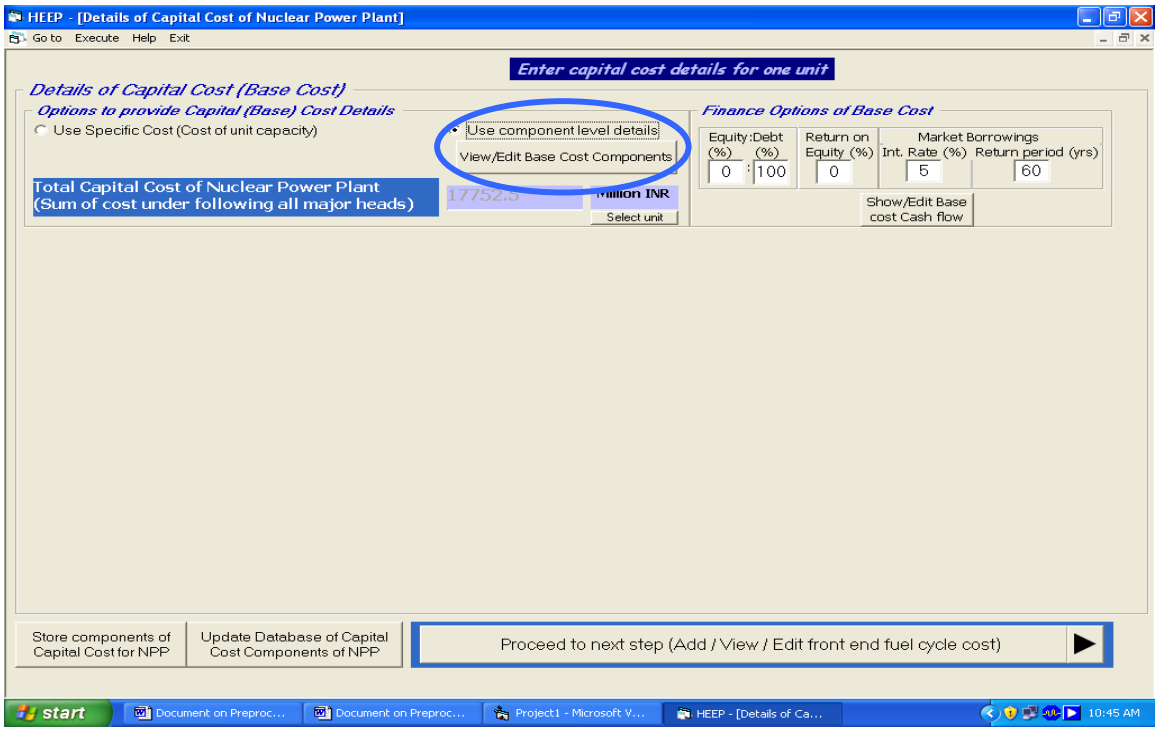
If new main head is to be added at the end of last main head in the table, ***click "Insert Main Head".*** A text box and two command buttons with signs "✓" and "X" will be visible. ***Enter main head description in text box and click "✓". Click "X" to cancel.***

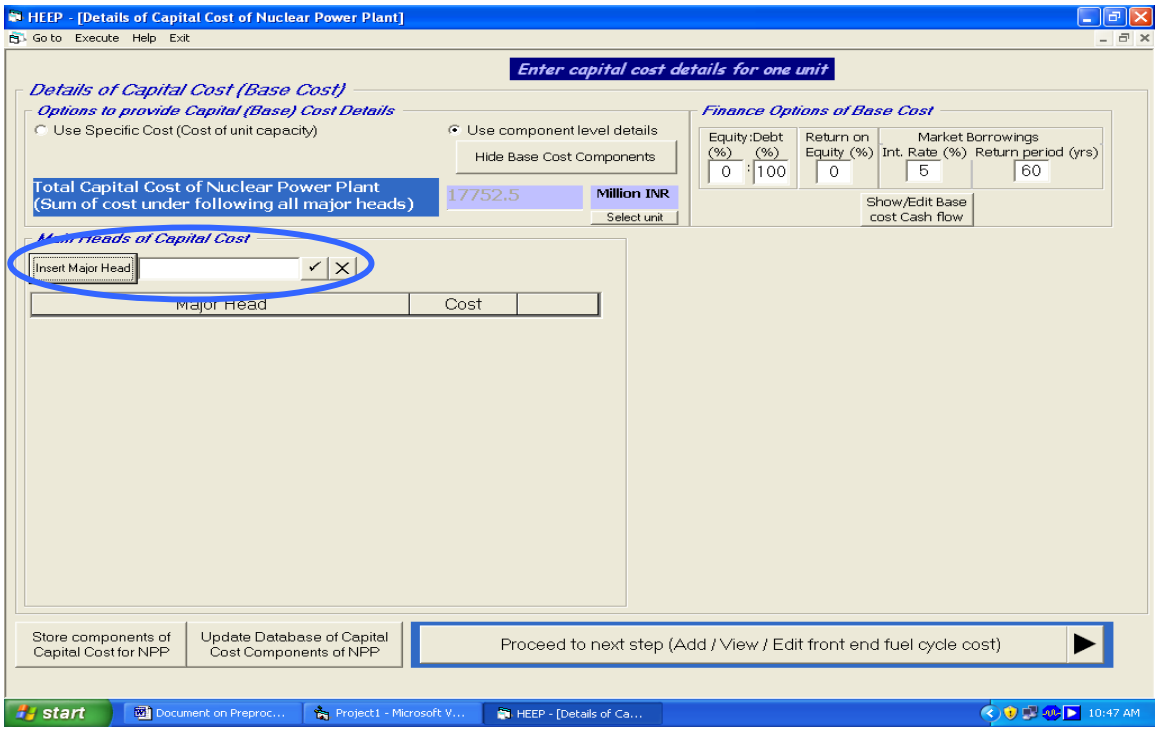
(Refer screenshots shown on subsequent pages)

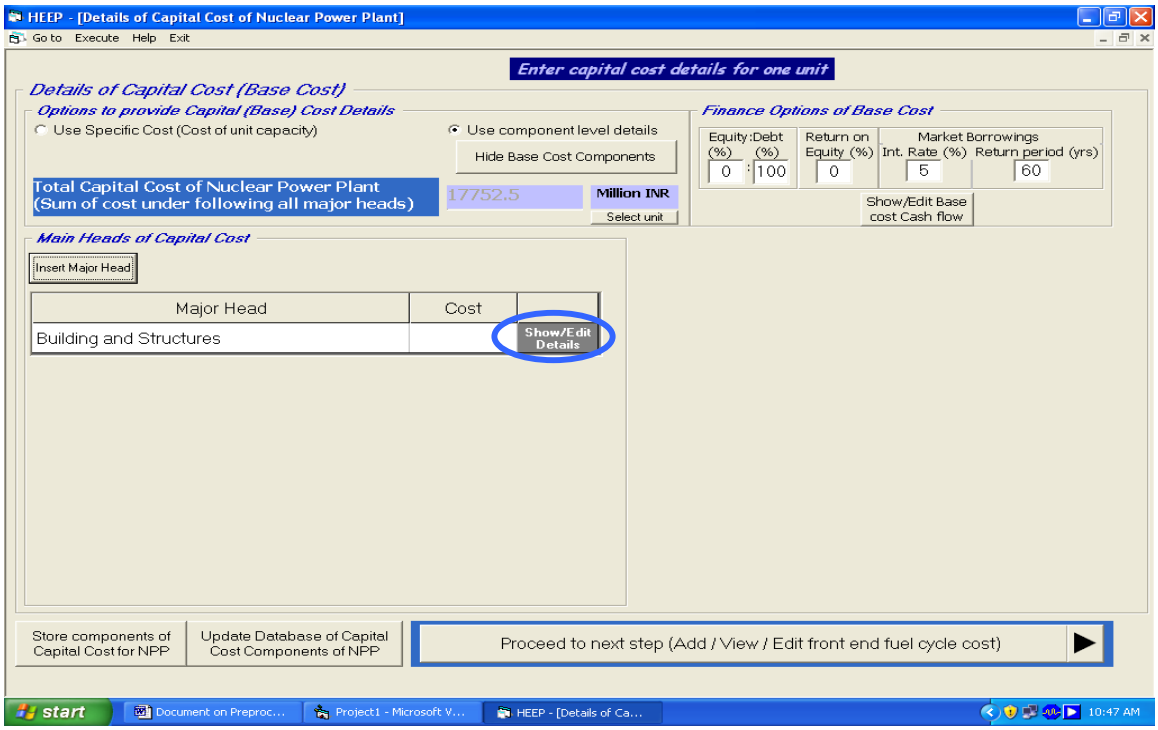
- Step-3: Once user enters description of the main head and clicks "✓" then this main head will get added to the table.

To enter cost of main head ***click "Show/Edit Details"***

(Refer screenshots shown on subsequent pages)


HEEP - [Details of Capital Cost of Nuclear Power Plant]
Go to Execute Help Exit
Enter capital cost details for one unit
Details of Capital Cost (Base Cost)
Options to provide Capital (Base) Cost Details
Use Specific Cost (Cost of unit capacity)
Use component level details
View/Edit Base Cost Components
Total Capital Cost of Nuclear Power Plant (Sum of cost under following all major heads)
17752.5
Million INR
Select unit
Finance Options of Base Cost
Equity:Debt (%) (%)
0 : 100
Return on Equity (%)
0
Market Borrowings
Int. Rate (%) Return period (yrs)
5 60
Show/Edit Base cost Cash flow
Store components of Capital Cost for NPP
Update Database of Capital Cost Components of NPP
Proceed to next step (Add / View / Edit front end fuel cycle cost)
start
Document on Preproc...
Document on Preproc...
Project1 - Microsoft V...
HEEP - [Details of Ca...
10:45 AM


HEEP - [Details of Capital Cost of Nuclear Power Plant]
Go to Execute Help Exit
Enter capital cost details for one unit
Details of Capital Cost (Base Cost)
Options to provide Capital (Base) Cost Details
Use Specific Cost (Cost of unit capacity)
Use component level details
Hide Base Cost Components
Total Capital Cost of Nuclear Power Plant (Sum of cost under following all major heads)
17752.5
Million INR
Select unit
Finance Options of Base Cost
Equity:Debt (%) (%)
0 : 100
Return on Equity (%)
0
Market Borrowings
Int. Rate (%) Return period (yrs)
5 60
Show/Edit Base cost Cash flow
Insert Major Head
Major Head
Cost
Store components of Capital Cost for NPP
Update Database of Capital Cost Components of NPP
Proceed to next step (Add / View / Edit front end fuel cycle cost)
start
Document on Preproc...
Project1 - Microsoft V...
HEEP - [Details of Ca...
10:47 AM



It may be noted that user cannot enter cost of main head in the column with heading "Cost". User will have to enter second level heads (minor head) for this main head and enter cost of the minor heads as described in the subsequent steps.

- Step-4: After clicking "Show/Edit Details" a frame for providing details of minor heads will be visible. User will have to provide details of minor head in this frame.

Similar to main head user have to ***click "Insert Sub Head"***

This again will open a text box and two command buttons with signs "✓" and "X". ***Enter the description of the sub head in the text box and click "✓" to accept the description. Click "X" to cancel.***

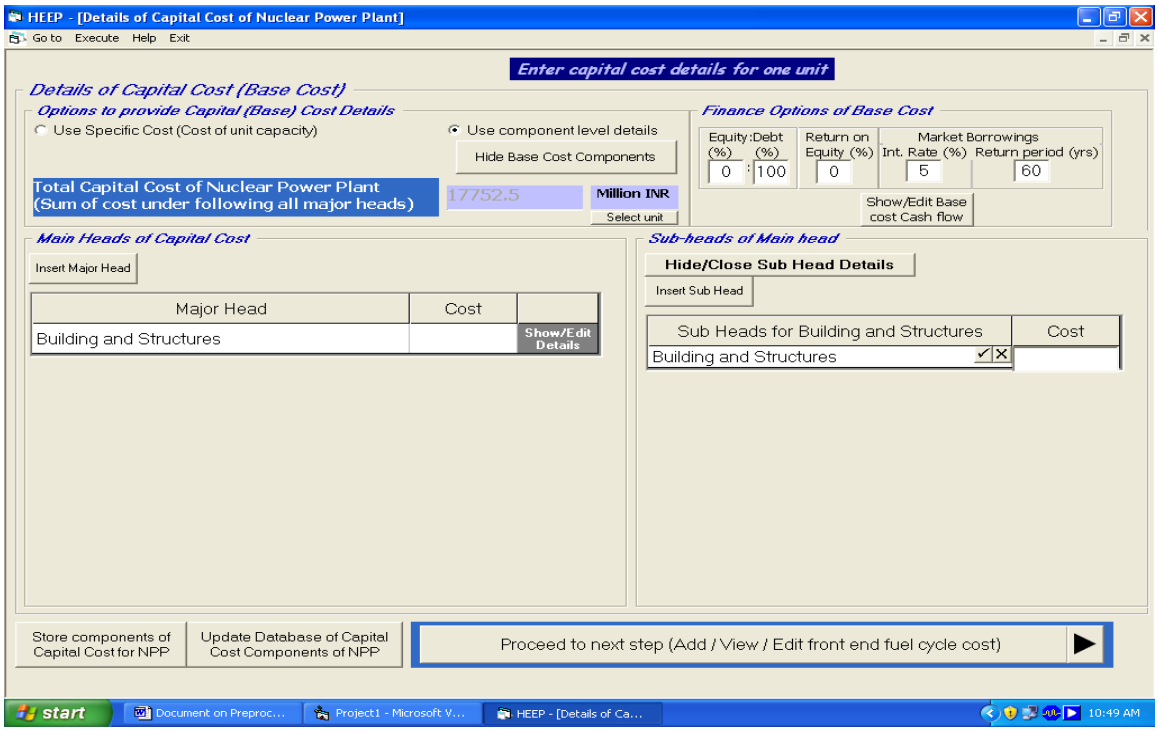
- Step-5: User will have to enter minor head cost in this table.

To enter cost of minor head ***click the cell corresponding to minor head under column head "cost"*** and ***enter cost of minor head followed by "✓" to accept the editing.***

As soon as user clicks "✓" after entering cost of minor head, programme adds cost of all minor heads and the sum of all minor head is written in the table showing all major heads on the left side of the screen. In this process, programme also adds updated costs of all major heads and writes in the text box showing total capital cost.

- Step-6: User can add more minor heads by repeating steps 4 & 5.

(Refer screenshots shown on next page)



5.3.2.2. Providing information for quick estimation of capital cost

Table 5-17: Information for quick estimation of base cost by the programme.

Information needed		
Nuclear power Plant	Hydrogen generating plant	Hydrogen transportation
• Specific cost of NPP (currency/MWth) e.g. if currency is USD then specific cost is expressed as 1200 USD/MWth or 2500 USD/MWth	• Total cost of hydrogen generation plant • Parameters to calculate capital cost of hydrogen storage facility (details of these parameters are described in section 5.3.2.2.1)	• Parameters to calculate capital cost of hydrogen transportation facility (details of these parameters are described in section 5.3.2.2.2)

5.3.2.2.1. Providing information for quick estimation of capital cost for hydrogen storage facility

When user selects option “Use in-built formulation for total base cost calculation”, user has to provide additional details for calculating capital cost component of hydrogen storage facility. These details will depend on type of hydrogen storage selected while entering technical details.

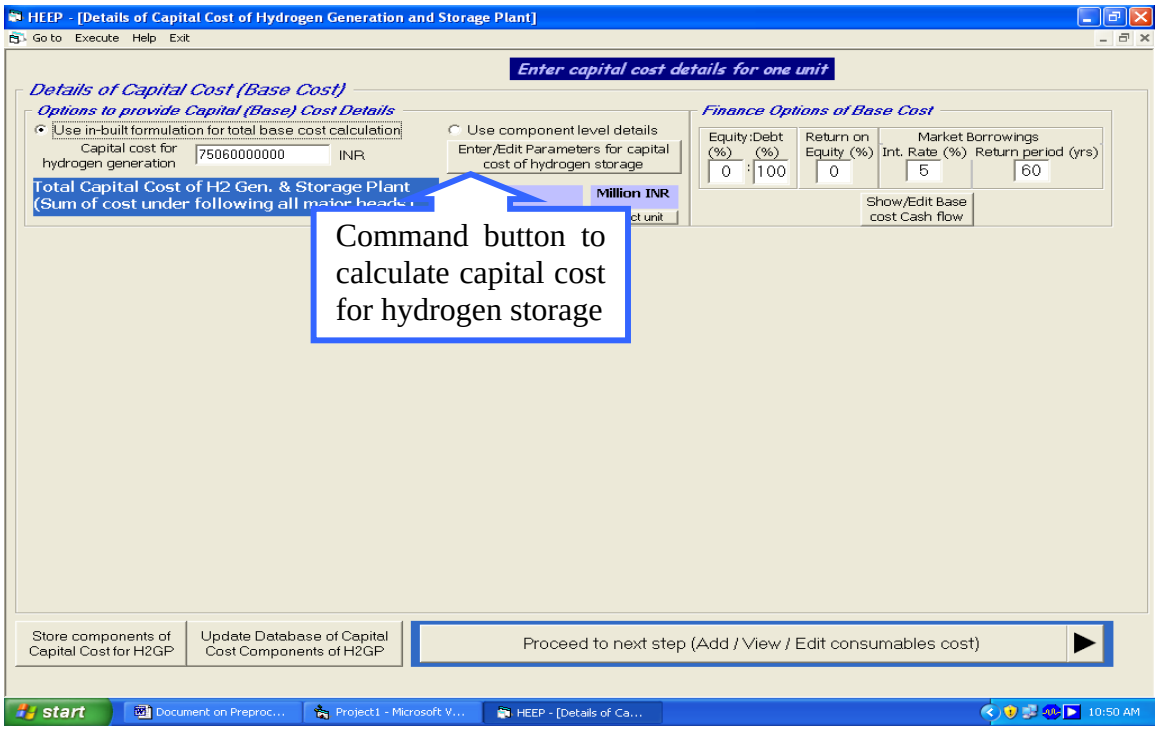


Figure 5-7: Capital cost details for hydrogen storage if user selects the option "Programme to calculate total base cost"

User shall click the command button "Enter/Edit parameters for capital cost of hydrogen storage" as shown in figure 5-7.

5.3.2.2.1(a) Providing details to calculate capital cost for gaseous storage

Following parameters given in Table 5-18 are to be provided to calculate cost of gaseous storage.

Table 5-18: Parameters for calculating capital cost of gaseous storage

Sl.	Parameter	Unit	Variable name
1	Capacity of reference compressor	kWe	H2SRefCompSize
2	Price of reference compressor	Cur/kWe	H2SRefCompCost
3	Pressure generated by reference compressor	Mpa	H2SRefComPr
4	Exponent for capacity adjustment to calculate cost of compressor of required capacity		H2SCompSizeExp
5	Exponent of pressure adjustment to calculate cost of compressor of required capacity		H2SComPrExp
6	Capacity of reference tank	kg	H2SRefTankSize
7	Price of reference tank	Cur/kg	H2SRefTankCost
8	Storage pressure of reference tank	Mpa	H2SRefTankPr
9	Exponent for capacity adjustment to calculate cost of tank of required capacity		H2STankSizeExp

Sl.	Parameter	Unit	Variable name
10	Exponent of pressure adjustment to calculate cost of tank of required capacity		H2STankPrExp

When user provides these details, programme will calculate cost of required compressor and tank using following formulae [1]. The compressor cost is calculated by

$$H2CompCost = H2SRfCompSize * H2SRfCompCost * \left(\frac{H2ComPower}{H2SRfCompSize}\right)^{H2SCompSizeExp} * \left(\frac{H2ComPr}{H2SRfCompPr}\right)^{H2SCompPr\,Exp}$$

And the tank cost is calculated by

$$H2TankCost = H2SRfTankSize * H2SRfTankCost * \left(\frac{H2StoreCap}{H2SRfTankSize}\right)^{H2STankSizeExp} * \left(\frac{H2CompPr}{H2SRfTankPr}\right)^{H2STankPr\,Exp}$$

Where H2ComPower capacity of the required compressor and H2ComPr is delivery pressure of the required compressor.

User may use following parameters as reference parameters for calculation of capital cost of compressor and tank cost.

Parameters [1] given in Table 5-19 may be used to calculate cost of gaseous storage. The reference year of the price of compressor and storage tank is 1995. User may escalate the price to present value by applying appropriate escalation rate.

Table 5-19: Reference values of parameters for calculating capital cost of compressor and storage tank

Sl.	Parameter	Reference value
1	Capacity of reference compressor	4000 Kwe
2	Price of reference compressor	1000 USD/kWe
3	Pressure generated by reference compressor	20 Mpa
4	Exponent for capacity adjustment to calculate cost of compressor of required capacity	0.8
5	Exponent of pressure adjustment to calculate cost of compressor of required capacity	0.18
6	Capacity of reference tank	227 kg
7	Price of reference tank	1323 USD/kg
8	Storage pressure of reference tank	20 Mpa
9	Exponent for capacity adjustment to calculate cost of tank of required capacity	0.75
10	Exponent of pressure adjustment to calculate cost of tank of required capacity	0.44

5.3.2.2.1(b) Providing details to calculate capital cost for liquid storage

Following parameters given in Table 5-20 are to be provided to calculate cost of liquid storage.

Table 5-20: Parameters for calculating capital cost of gaseous storage

Sl.	Parameter	Unit	Variable name
1	Capacity of reference liquifier	Kg/hr	H2SRefLiqSize
2	Price of reference liquifier	Cur/ Kg/hr	H2SRefLiqCost
3	Exponent for capacity adjustment to calculate cost of compressor of required capacity		H2SLiqSizeExp
4	Storage capacity of reference Dewar	kg	H2SRefDewSize
5	Price of reference Dewar	Cur/kg	H2SRefDewCost
6	Exponent for size adjustment to calculate Dewar cost of required capacity		H2SDewSizeExp

When user provides these details, programme will calculate cost of required compressor and tank using following formulae [1]. The cost of liquifier is calculated by

$$H2LiquifierCost = H2SRfLiqSize * H2SRfLiqCost * \left(\frac{H2GenCap * (1 + 1 - e^{-H2BOR * H2StoreTime}) / 8760.0}{H2SRfLiqSize} \right)^{H2SLiqSizeExp}$$

And the Dewar cost is calculated by

$$H2DewCost = H2SRfDewSize * H2SRfDewCost * \left(\frac{H2StoreCap}{H2SRfDewSize} \right)^{H2SDewkSizeExp}$$

Where H2GenCap is hydrogen generation capacity, H2BOR is boil-off rate and H2StoreTime is storage time. H2StoreCap is hydrogen storage capacity derived based on storage time and generation capacity. These parameters are described in the section dealing with technical details related to hydrogen generation and storage facility.

User may use following parameters as reference parameters for calculation of liquifaction capital cost.

Parameters [1] given in Table 5-21 may be used to calculate cost of liquid storage. The reference year of the price of liquifier and Dewar is 1995. User may escalate the price to present value by applying appropriate escalation rate.

Table 5-21: Reference values of parameters for calculating capital cost of compressor and storage Dewar for liquefied storage

Sl.	Parameter	Reference value
1	Capacity of reference liquifier	454 kg/h
2	Price of reference liquifier	44,100 USD/kg/hr
3	Exponent for capacity adjustment to calculate cost of compressor of required capacity	0.65
4	Capacity of reference Dewar	45 kg
5	Price of reference Dewar	441 USD/kg
6	Exponent for capacity adjustment to calculate cost of tank of required capacity	0.7

5.3.2.2.1(c) Providing details to calculate capital cost for hydride storage

Following parameters given in Table 5-22 are to be provided to calculate cost of hydride storage. When user provides these details, programme will calculate cost of required compressor and tank using following formula [1].

$$H2HydStoreCost = H2HydStoreRate * H2GenCap * H2StoreTime / 8760.0$$

Where H2GenCap is hydrogen generation capacity, and H2StoreTime is storage time. These parameters are described in the section dealing with technical details related to hydrogen generation and storage facility.

Table 5-22: Parameters for calculating capital cost of gaseous storage

Sl.	**Parameter**	**Unit**	**Variable name**
1	Specific cost of hydride storage	Cur / kg	H2HydStoreRate

Table 5-23: Reference values of parameters for calculating hydride storage capital cost of compressor and storage Dewar for liquefied storage

Sl.	**Parameter**	**Reference value**
1	Specific cost of hydride storage	2200 USD/kg

5.3.2.2.2. Providing information for quick estimation of capital cost for hydrogen transportation facility

When user selects option “Use in-built formulation for total base cost calculation” user has to provide details for calculating capital cost of hydrogen transportation facility depending on type of hydrogen transportation selected while entering technical details.

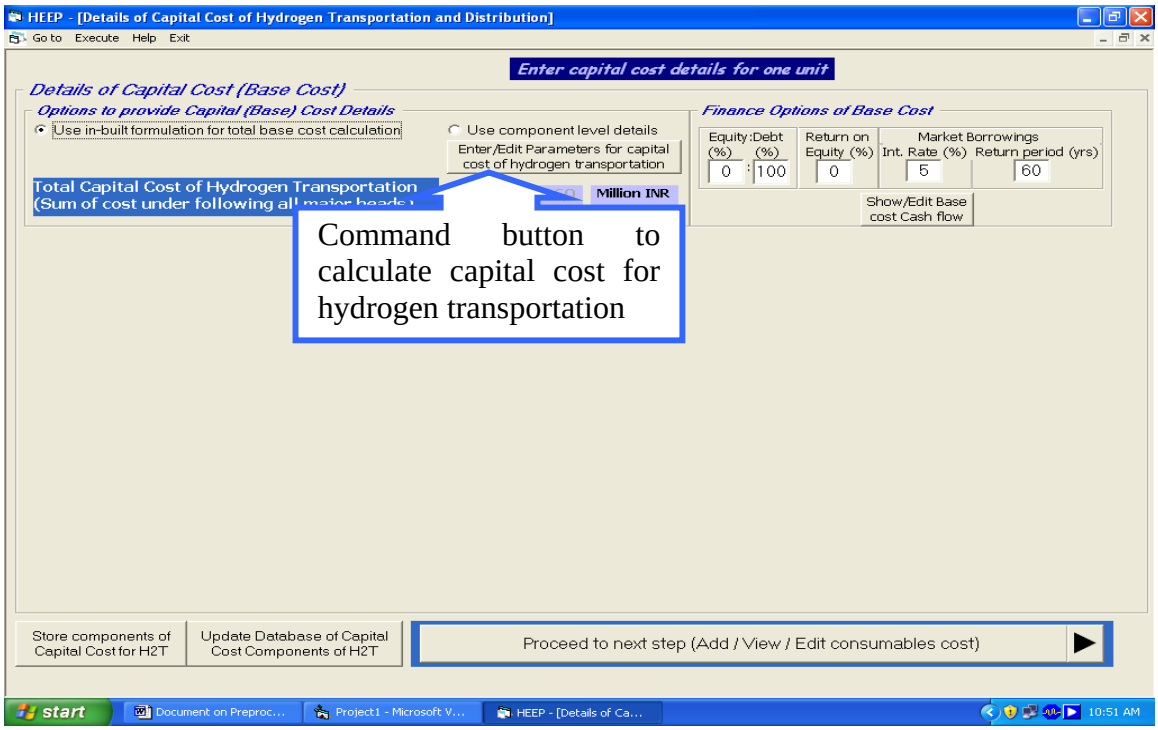


Figure 5-8: Capital cost details for hydrogen transportation if user selects the option "Programme to calculate total base cost"

User shall click the command button "Enter/Edit parameters for capital cost of hydrogen transportation" as shown in figure 5-8.

5.3.2.2.2(a) Providing details to calculate capital cost for pipe line transportation

Following parameters given in Table 5-24 are to be provided to calculate cost of transportation of hydrogen through pipe line.

Table 5-24: Parameters for calculating capital cost for transportation through pipeline

Sl.	Parameter	Unit	Variable name
1	Capacity of reference compressor	kWe	H2TRefCompSize
2	Price of reference compressor	Cur/kWe	H2TRefCompCost
3	Pressure generated by reference compressor	Mpa	H2TRefComPr
4	Exponent for capacity adjustment to calculate cost of compressor of required capacity		H2TCompSizeExp
5	Exponent of pressure adjustment to calculate cost of compressor of required capacity		H2TComPrExp
6	Specific cost of pipeline	Cur/m	H2TPLPrice

When user provides these details, programme will calculate cost of required compressor and pipeline cost using following formula [1].

$$H2TCompCost = H2TRfCompSize * H2TRfCompCost * \left(\frac{H2TComPower}{H2TRfCompSize}\right)^{H2TCompSizeExp} * \left(\frac{H2TCom\,\mathrm{Pr}}{H2TRfComp\,\mathrm{Pr}}\right)^{H2TComp\,\mathrm{Pr}\,Exp}$$

Where H2TComPower capacity of the required compressor and H2TComPr is delivery pressure of the required compressor. These parameters and their calculation are described in the section on technical details of transportation.

The cost of pipeline is calculated simply by multiplying distance of transportation (*H2TransDist*) and specific cost of pipeline (*H2TPLPrice*). The specific cost of pipeline may include cost of land, installation charges.

Parameters [1] given in Table 5-25 may be used to calculate capital cost of compressor to transport hydrogen through pipeline. The reference year of the price of compressor is 1995. User may escalate the price to present value by applying appropriate escalation.

Table 5-25: Reference values of parameters for calculating compressor cost

Sl.	Parameter	Reference value
1	Capacity of reference compressor	4000 Kwe
2	Price of reference compressor	1000 USD/kWe
3	Pressure generated by reference compressor	20 Mpa
4	Exponent for capacity adjustment to calculate cost of compressor of required capacity	0.8
5	Exponent of pressure adjustment to calculate cost of compressor of required capacity	0.18

5.3.2.2.2(b) Providing details to calculate capital cost for vehicular transportation

Following parameters given in Table 5-26 are to be provided to calculate capital cost of vehicular transportation of hydrogen.

Table 5-26: Parameters for calculating capital cost of vehicular transportation

Sl.	Parameter	Unit	Variable name
1	Cost of one vehicle	Cur	TransVehPrice

When user provides these details, programme will calculate total cost of required number of vehicles (TransVehCost) by multiplying cost of one vehicle with total number of vehicles required for transportation of hydrogen. Total number of vehicles is derived from capacity of hydrogen generation (H2GenCap), distance of transportation (H2TransDist), the capacity of vehicle to transport hydrogen (TransVehCap), loading/unloading time (TransVehLoadTime), and speed of vehicle (TransVehSpeed). These details are described in the section pertaining to technical details.

Following formulae are used to determine total number of vehicles required for hydrogen transportation.

Number of trips to be done in one year $NTrips = H2GenCap / TransVehCap$

Time taken per trip is given by $TripTime = \frac{2 * H2TransDist}{1000 * TransVehSpeed}$

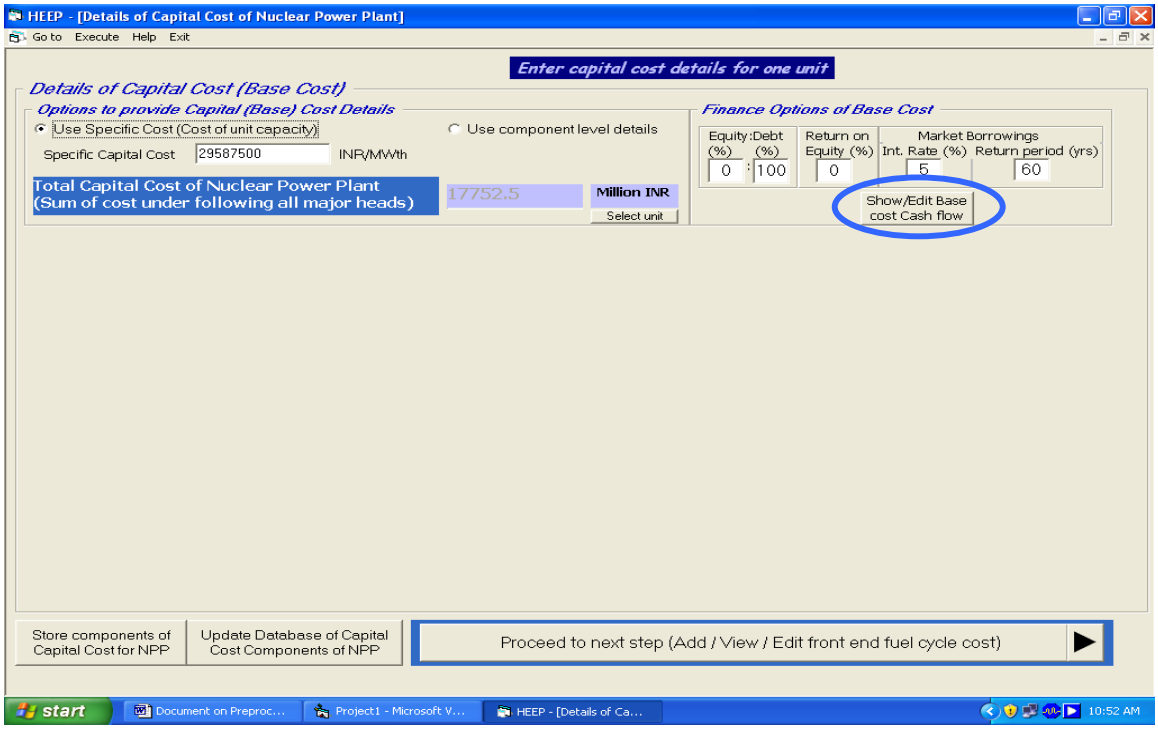
Total number of vehicles required is $NVeh = \frac{NTrips * (TripTime + TransVehLoadTime)}{8760.0}$

5.3.2.3. Providing cash flow during construction and option to calculate interest during construction

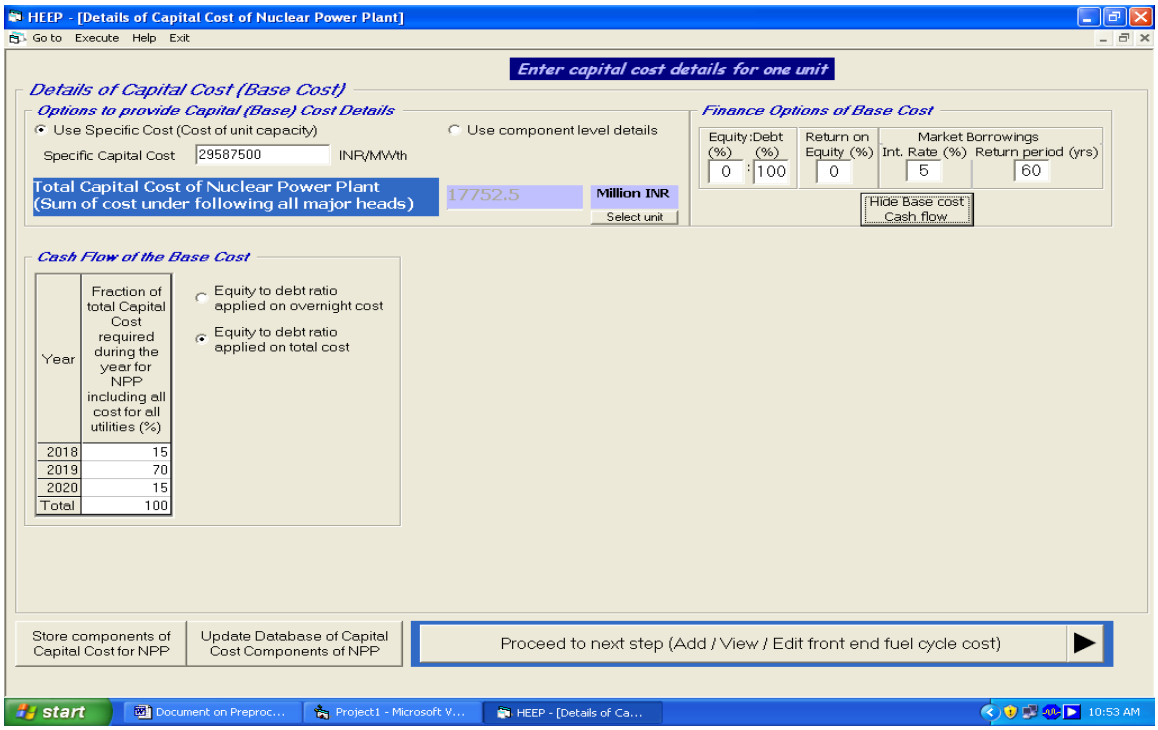
After entering capital cost details, user shall provide fraction of capital cost required in each year during construction period.

To enter cash flow during construction ***click "Show/Edit Base Cost Cash flow"***

After "Show/Edit Base Cost Cash flow" is clicked, table to provide fraction of total capital cost required in each year during construction period will appear.



Two options have been provided for calculation of interest during construction. In one option, equity to debt ratio is applied on overnight cost and in the other option the equity to debt ratio is applied on total cost, which also includes interest during construction.



Select option for calculation of interest during construction.

In case of nuclear power plant, if user has selected electricity generation as other applications of nuclear power plant then user will have to provide fraction of total capital cost required for electricity generating components/systems in the year. It may be noted that this fraction will be subset of total fraction required during that year. Following example illustrates this aspect.

Example illustrating cash flow during construction for the nuclear power plant which also generates electricity: If total base cost of nuclear power plants including components and systems required for electricity generation is 1000 units. The construction period is 2 years. Among the total amount required, 400 units are required in the first year and 600 units are required during second year. Out of these 1000 units is 50 units are required in the first year for construction of building required for electricity generation and 200 units are required in second year for purchase of electricity generation equipment. The construction starts in the year 2010 and ends in the year 2011 then user shall enter following values given in table 5-27 to provide cash flow information.

Table 5-27: Example for cash flow during construction

Year	Fraction of total capital cost required during the year for NPP including cost for all applications	Fraction of total capital cost required during the year for NPP components generating electricity
2010	0.4	0.05
2011	0.6	0.2

5.3.2.4. Next step after providing capital cost details

After entering all the capital cost details, next step is to provide details of cost required for running facilities for hydrogen generation. The first component of running cost for nuclear power plant is front end of fuel cycle cost and in case of hydrogen generation, storage and transportation is cost of consumables and locked in inventory.

Click the button "Proceed to next step (Add / View / Edit cost components of front end fuel cycle cost)" to enter front end fuel cycle cost of nuclear power plant (If user has completed entering capital cost details of for nuclear power plant.)

Click the button "Proceed to next step (Add / View / Edit Consumables Cost of H2GP or H2T)" to enter consumables cost of hydrogen generation and storage plant or hydrogen transportation facility (If user has completed entering capital cost for hydrogen generation or hydrogen transportation.)

5.3.3. Running cost details

As described in Table 5-28 cost of fuel cycle (front end and back end), cost of consumables and locked in inventories, and operation and maintenance cost are included under running cost. Among these, fuel cycle cost forms component of running cost of only the nuclear power plant.

Table 5-28: Running cost components

	Running Cost Component	Applicability for type of plant or facility		
		Nuclear power plant	Hydrogen generation and storage plant	Hydrogen transportation and distribution
1	Cost of fuel cycle (front end)	✓	X	X
2	Cost of fuel cycle (back end)	✓	X	X
3	Cost of consumables	✓	✓	✓
4	O&M cost	✓	✓	✓

5.3.3.1. Providing front end fuel cycle cost for nuclear power plant

After entering details of capital investments for nuclear power plant, the next step is to provide cost details of front end of fuel cycle. User is required to provide isotopic composition of the fuel (% weight), period of usage of the fuel type, initial inventory and annual feed and cost details of main processes of fuel manufacturing. User can open the form for entering front end fuel cycle details of nuclear power plant using any one of the following steps:

Click the button "Proceed to next step (Add / View / Edit front end fuel cycle cost of NPP)" to enter front end fuel cycle cost of nuclear power plant if user has completed entering capital cost for nuclear power plant for the nuclear power

OR

Click "Go to" – "Cost Components" from pull down menu followed by clicking "Add or Edit or View Details" of Front End Fuel Cycle Cost.

OR

- ***In the flowsheet window click the button "Cost Components of Nuclear Power Plant" (***To go to flowsheet, from pull down menu ***click "Go to" – "Flowsheet"*) *OR Click "Go to" – "Cost Components" from pull down menu***
- ***Click "Add or Edit or View Details" of Front End Fuel Cycle Cost***

The window for entering details of front end fuel cycle cost is shown in the figure 5-9.

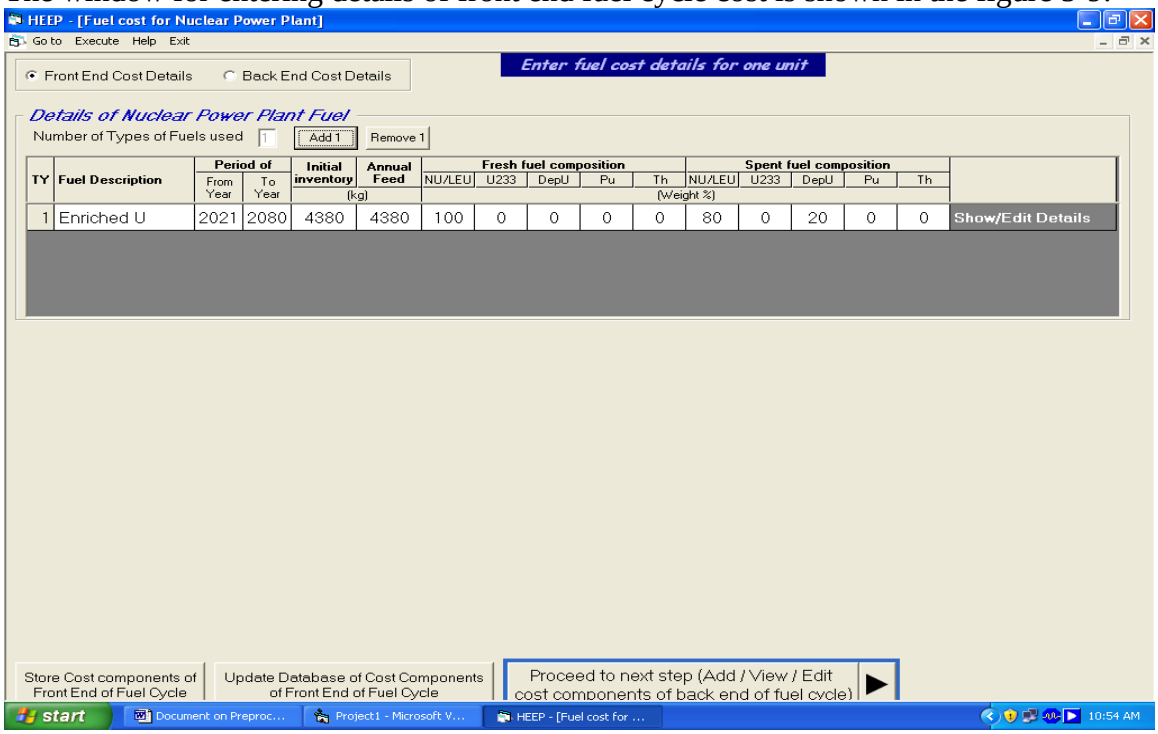


Figure 5-9: Window for entering front end fuel cycle cost details.

The first step is to create or add the new fuel type and provide details given in the Table 5-29. User can increase or decrease the fuel configurations.

Click "Add 1" button to increase the fuel types and "Remove 1" button to delete the last fuel type in the table.

Table 5-29: Details of fuel types to be provided by the user

Sl.	Parameter	Unit	Variable name
1	Fuel description		FuelTy
2	Year for start of usage of fuel type	Calendar year	PeriodFrom
3	Year to end of usage of fuel type	Calendar year	PeriodTo
4	Initial inventory	kg	FuelWtIni
5	Annual feed	kg	FuelWtAnn
6	Weight percent[^] of NU[#] or LEU[@] in fresh fuel	%	NatOrLEU_Fresh
7	Weight percent of U233 in fresh fuel	%	U233_Fresh
8	Weight percent of DepU[*] in fresh fuel	%	DepU_Fresh
9	Weight percent of plutonium in fresh fuel	%	Pu_Fresh
10	Weight percent of thorium in fresh fuel	%	Th_Fresh
11	Weight percent of NU or LEU in spent fuel	%	NatUOrLEU_Spent
12	Weight percent of U233 in spent fuel	%	U233_Spent
13	Weight percent of DepU in spent fuel	%	DepU_Spent
14	Weight percent of plutonium in spent fuel	%	Pu_Spent
15	Weight percent of thorium in spent fuel	%	Th_Spent

User can provide details of maximum four fuel types that could be used in nuclear reactors at different times and for different periods. Following statement illustrates example of using of different fuel types for different time periods of reactor operation.

Example: Reactors using U^{233}-Th based fuel in their equilibrium core configuration, may require U^{235}-Th or Pu-Th fuel initially to convert Th in to U^{233}. The converted U^{233} would be used in U^{233}-Th based fuel. Thus, two types of fuels would be used viz. U^{235}-Th or Pu-Th based fuel in the initial period (say for first 15 years of operation) and U^{233}-Th based fuel for rest of the reactor life. If the reactor operation begins in the year 2016 then U^{235}-Th or Pu-Th based fuel would be used from 2016 to 2030 followed by U^{233}-Th based fuel from 2031 to 2075 if operating period of the reactor is considered to be of 60 years.

After entering details of nuclear fuel types user has to provide cost details of important steps of fuel manufacturing. User can select any one or more than one processes among following four important steps of fuel manufacturing. (i) Purchase of fuel materials (NatU or LEU, U233, DepU, Plutonium and thorium) (ii) Conversion to desired chemical form for these materials (ii) Enrichment of uranium (if required) (iv) Fabrication of fuel.

Click the checkbox of fuel manufacturing step.

Once the fuel manufacturing process is selected, user has to provide losses during the process, advance period for completion of each process and enter cost of each process.

[^] Weight percent of the total fuel; not to be confused with enrichment
[#] NU: Natural Uranium
[@] LEU: Low Enriched` Uranium
[*] DepU: Depleted Uranium

Click "Show/Edit Details" under the last column of the table with heading "Action".

After clicking the button "Show/Edit Details", another table for entering cost details will be opened, in which user has to enter relevant details.

It is to be noted that while entering the cost details of each process, the cost values for manufacturing of one kg of finished fuel.

5.3.3.1.1. Next step after providing cost details for front end of fuel cycle.

After entering all the details of front end fuel cycle cost for nuclear power plant user may follow steps described below:

- ***Click the button "Proceed to next step (Add / View / Edit cost components of back end fuel cycle)" to enter back end fuel cycle cost of nuclear power plant***
- User may also ***click radio button "Back End Cost details"***

5.3.3.2. Providing back end fuel cycle cost for nuclear power plant

After entering front-end fuel cycle cost details of nuclear power plant, the next step is to provide cost details of back end of fuel cycle. User can open the form for entering back end fuel cycle details of nuclear power plant using any one of the following steps:

Click the button "Proceed to next step (Add / View / Edit cost details of back en dof fuel cycle)" to enter back end fuel cycle cost of nuclear power plant if user has completed entering cost details of front end of fuel cycle.

OR

Click "Go to" – "Cost Components" from pull down menu followed by clicking "Add or Edit or View Details" of back end fuel cycle cost.

OR

- ***In the flowsheet window click the button "Cost Components of Nuclear Power Plant" (***To go to flowsheet, from pull down menu ***click "Go to" – "Flowsheet"***) ***OR Click "Go to" – "Cost Components" from pull down menu***
- ***Click "Add or Edit or View Details" of back end fuel cycle cost***

User is required to choose among two options Viz. (i) Direct disposal of spent fuel and (ii) Reprocessing of spent fuel.

Click the corresponding radio button to select the option for back end of fuel cycle .

If option of direct disposal is selected then, user has to provide the following:

- Spent fuel transportation charges
- Spent fuel disposal charges.

If option of "reprocessing" is selected, user has to provide following additional details:

- Spent fuel reprocessing charges
- Cost of recovered uranium
- Cost of recovered plutonium
- Cost of recovered thorium

The window for entering details of back end fuel cycle cost for " Direct Disposal" option is shown in the figure 5-10.

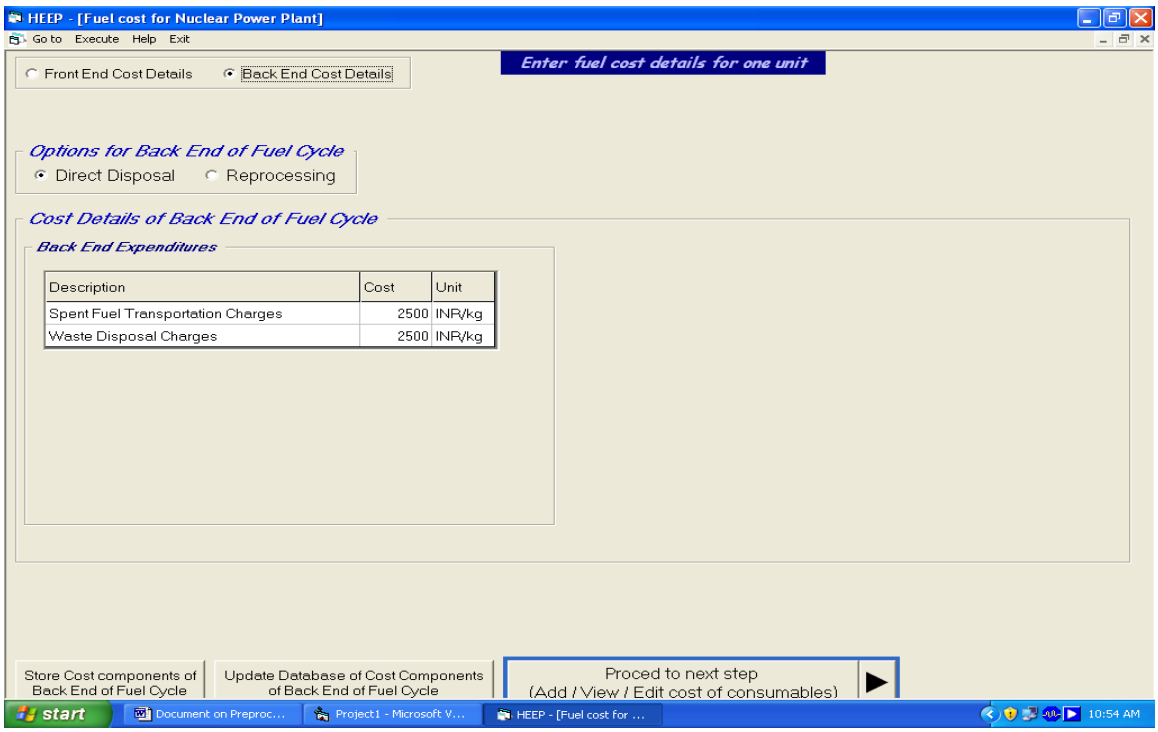


Figure 5-10: Back end fuel cycle cost details for "Direct Disposal" option.

5.3.3.2.1. Next step after providing cost details for back end of fuel cycle.

After completion of entering details of back end fuel cycle cost for nuclear power plant user may follow steps described below:

Click the button "Proceed to next step (Add / View / Edit cost of consumables)" to enter cost details for consumables of nuclear power plant

5.3.3.3. Providing cost details for consumables and locked in inventory of materials required for running all facilities generating nuclear hydrogen

The next step after entering all the details of capital investments for hydrogen generation facility as well as for hydrogen transportation and after entering fuel cycle cost details for nuclear power plant is to provide cost of consumables and locked in inventory required for running respective facilities generating nuclear hydrogen. User can open form/window to enter cost of consumables and locked in inventory using any one of the following steps:

Click the button "Proceed to next step (Add / View / Edit cost of consumables)" to enter cost details of consumables and locked in inventory of materials, if user has completed entering fuel cycle details of nuclear power plant or details of capital investments for hydrogen generation and storage facility or hydrogen transportation.

OR

Click "Go to" – "Cost Components" from pull down menu followed by clicking "Add or Edit or View Details" of cost of consumables.

OR

- ***In the flowsheet window click the button "Cost Components of Nuclear Power Plant" (***To go to flowsheet, from pull down menu ***click "Go to" – "Flowsheet"***) ***OR Click "Go to" – "Cost Components" from pull down menu***
- ***Click "Add or Edit or View Details" of cost of consumables.***

The window for entering cost details for consumables is shown in the figure 5-11.

The first step is to create or add the new consumable type and provide details given in the Table 5-30. User can increase or decrease the consumable type.

Click "Add 1" button to increase the consumable type and "Remove 1" button to delete the last consumable type in the table.

Table 5-30: Details of consumable types to be provided by the user

Sl	Parameter	Unit	Variable name for		
			Nuclear plant	H2 generation plant	H2 transportation
1	Consumable description		ConsumTy_NPP	ConsumTy_H2GP	ConsumTy_H2T
2	Unit for quantity	Kg, etc.	ConsumUnit_NPP	ConsumUnit_H2GP	ConsumUnit_H2T
3	Initial inventory	kg	ConsumIQ_NPP	ConsumIQ_H2GP	ConsumIQ_H2T
4	Annual feed	kg	ConsumAF_NPP	ConsumAF_H2GP	ConsumAF_H2T

Sl	Parameter	Unit	Variable name for		
5	Cost of consumable	Cur/ unit	ConsumRate_NPP	ConsumRate_H2GP	ConsumRate_H2T
6	Advanced period	Year	ConsumAdvP_NPP	ConsumAdvP_H2GP	ConsumAdvP_H2T

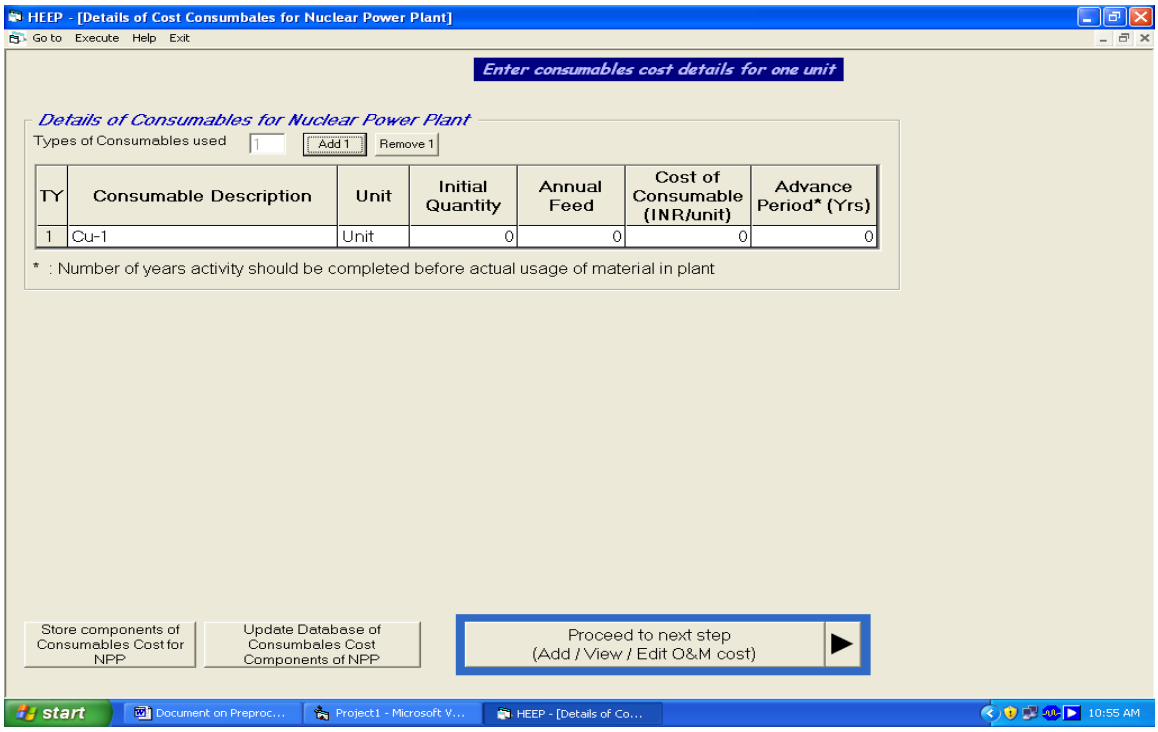


Figure 5-11: Window for entering cost details of consumables.

5.3.3.3.1. Next step after providing cost of consumables

After entering all the cost details of consumables for nuclear power plant user may follow steps described below:

Click the button "Proceed to next step (Add / View / Edit O&M cost)"

5.3.3.4. Providing O&M cost details

After entering cost details of consumables and locked in inventory of facility the next step is to provide details of O&M cost. It may be noted that the cost of large scale refurbishment of the facility is included as part of O&M cost. User can open form/window for entering O&M cost details using any one of the following steps:

Click the button "Proceed to next step (Add / View / Edit O&M cost)" to enter O&M cost details, if user has completed entering details of consumables and locked in inventory required for operating the facility.

OR

Click "Go to" – "Cost Components" from pull down menu followed by clicking "Add or Edit or View Details" of O&M cost.

OR

- ***In the flowsheet window click the button "Cost Components of Nuclear Power Plant"*** (To go to flowsheet, from pull down menu ***click "Go to" – "Flowsheet"***) ***OR Click "Go to" – "Cost Components" from pull down menu***
- ***Click "Add or Edit or View Details" of O&M cost.***

User has two options for entering O&M cost details:

(i) Providing component level details for annual O&M cost
(ii) Providing O&M cost as block estimate for all years (% of total capital cost)

5.3.3.4.1. Providing component level details for annual O&M cost

In this option, user has to provide component level details for each year during operating period. User can consider sub-heads such as routine maintenance cost, electricity charges for operating the facility, wages, and land lease charges if any etc. as part of O&M cost.

Follow the steps given below to provide component level details for annual O&M cost.

- Step-1: ***Click command button "View/Edit Year-wise O&M Cost" to view/edit/add annual O&M cost.***

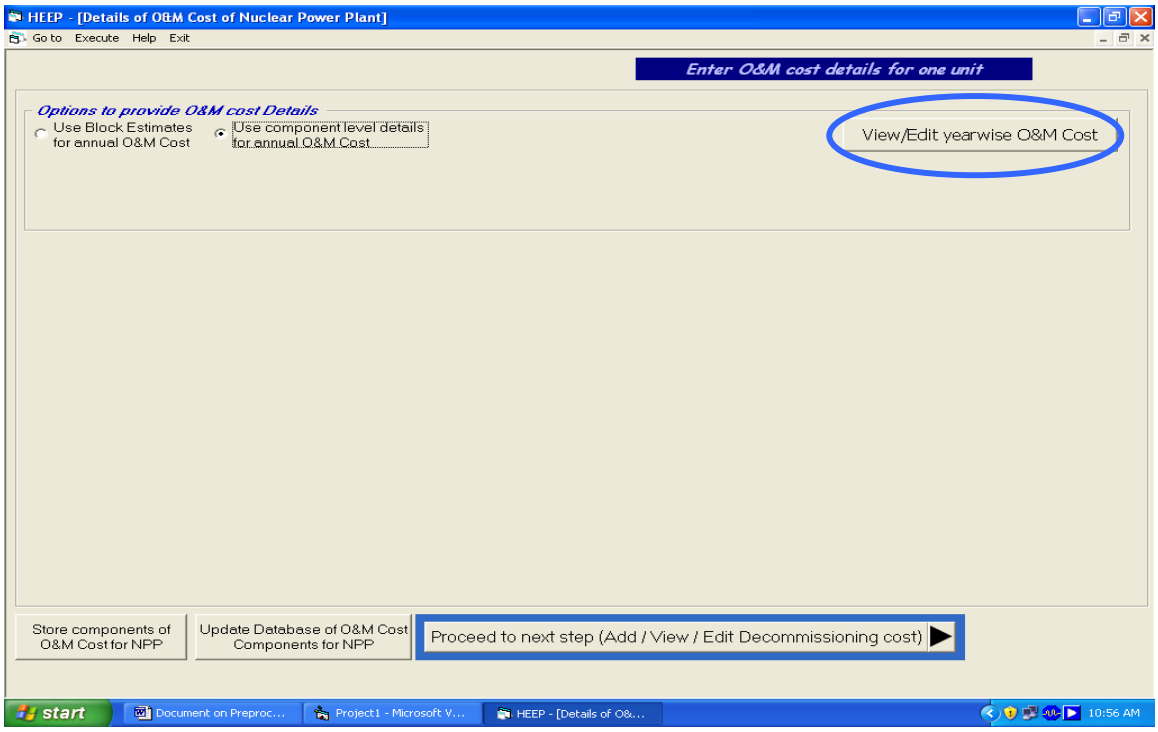
(Refer screenshots on the subsequent pages)

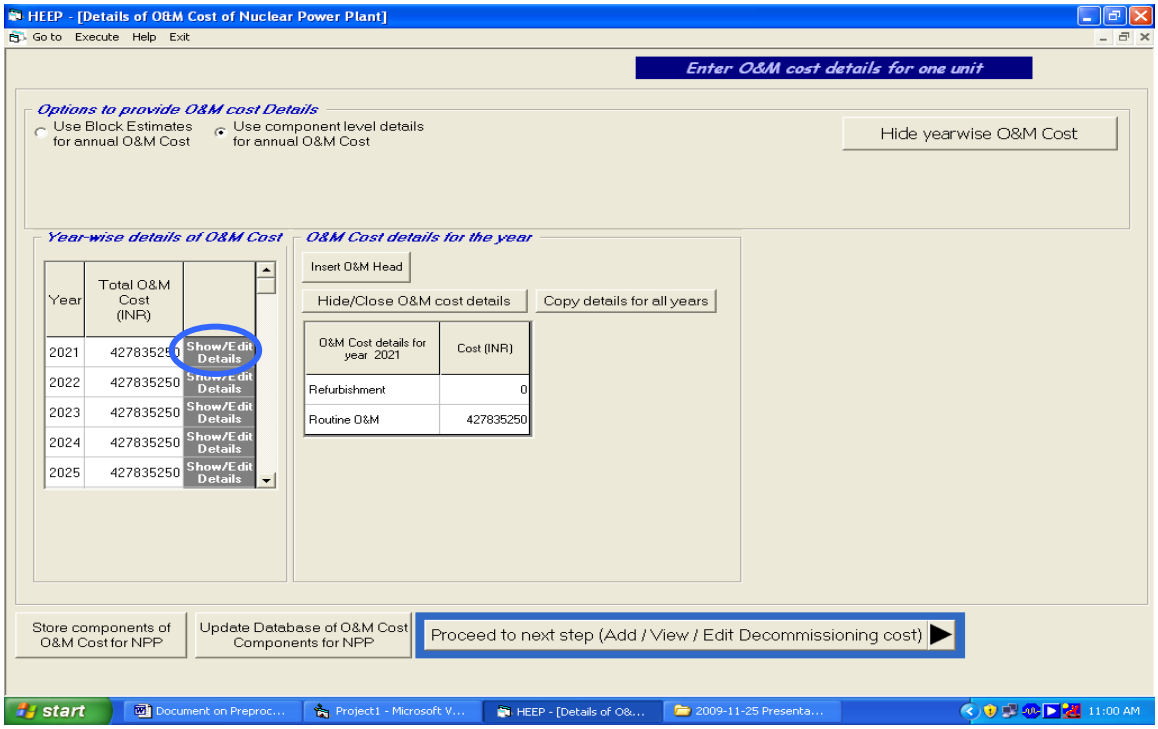
- Step-2: Frame showing year-wise total O&M cost will be visible. User cannot enter total O&M cost for the each year. User has to ***click "Show/Edit Details"*** in the last column of the corresponding year to provide O&M cost details for the relevant year.

- Step-3: After clicking "Show/Edit Details" a frame for providing details of O&M head will be visible. User will have to provide details of O&M head in this frame.

Similar to main head user have to ***click "Insert O&M Head".*** This will open a text box and two command buttons with signs "✓" and "X". ***Enter the description of the O&M head in the text box and click "✓" to accept the description. Click "X" to cancel.***

[It may be noted that the first head shown in the table is always "Refurbishment"]


HEEP - [Details of O&M Cost of Nuclear Power Plant]
Go to Execute Help Exit
Enter O&M cost details for one unit
Options to provide O&M cost Details
Use Block Estimates for annual O&M Cost
Use component level details for annual O&M Cost
View/Edit yearwise O&M Cost
Store components of O&M Cost for NPP
Update Database of O&M Cost Components for NPP
Proceed to next step (Add / View / Edit Decommissioning cost)
start
Document on Preproc...
Project1 - Microsoft V...
HEEP - [Details of O&...
10:56 AM


HEEP - [Details of O&M Cost of Nuclear Power Plant]
Go to Execute Help Exit
Enter O&M cost details for one unit
Options to provide O&M cost Details
Use Block Estimates for annual O&M Cost
Use component level details for annual O&M Cost
Hide yearwise O&M Cost
Year-wise details of O&M Cost
Year
Total O&M Cost (INR)
2021 427835250 Show/Edit Details
2022 427835250 Show/Edit Details
2023 427835250 Show/Edit Details
2024 427835250 Show/Edit Details
2025 427835250 Show/Edit Details
O&M Cost details for the year
Insert O&M Head
Hide/Close O&M cost details
Copy details for all years
O&M Cost details for year 2021
Cost (INR)
Refurbishment 0
Routine O&M 427835250
Store components of O&M Cost for NPP
Update Database of O&M Cost Components for NPP
Proceed to next step (Add / View / Edit Decommissioning cost)
start
Document on Preproc...
Project1 - Microsoft V...
HEEP - [Details of O&...
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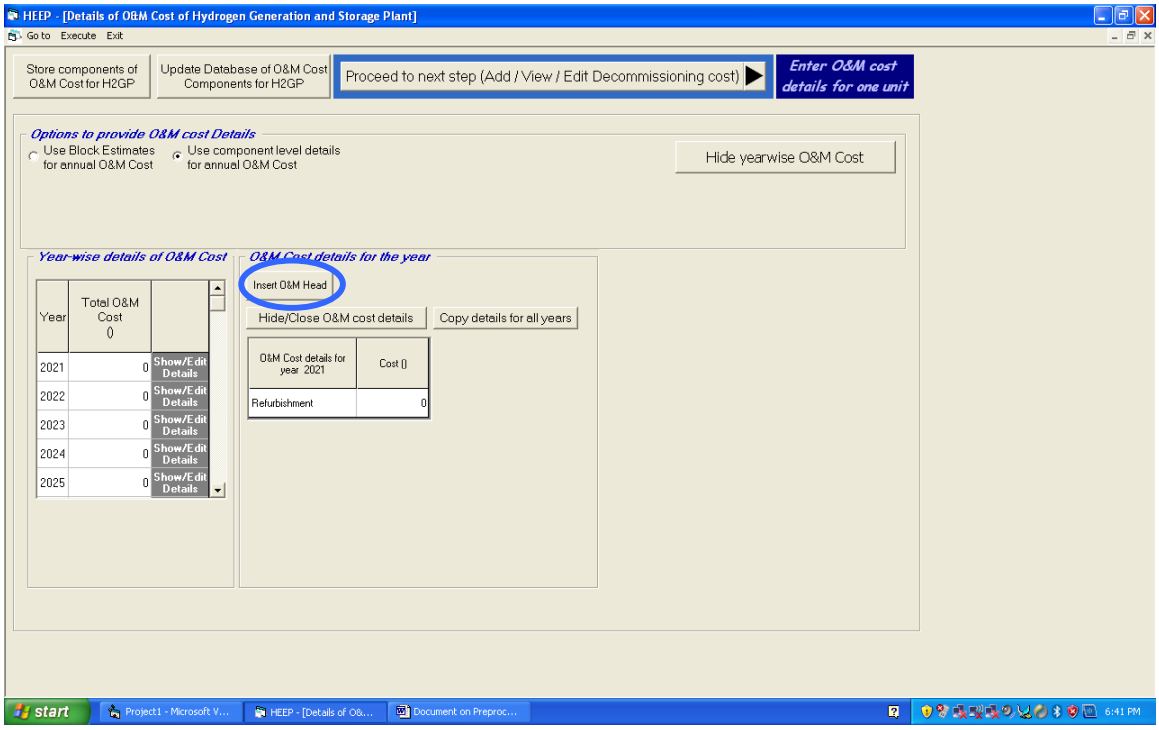


- Step-4: User will have to enter cost of O&M head in this table.

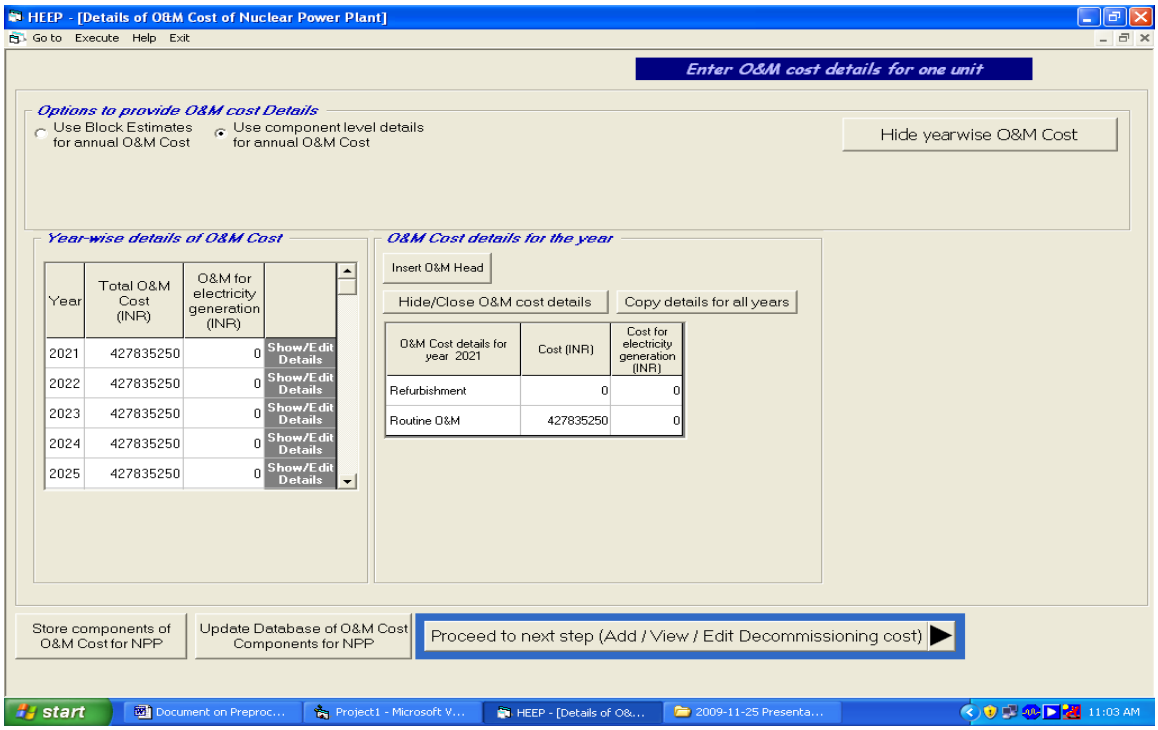
To enter cost of minor head ***click the cell corresponding to O&M head under column head "cost"*** and ***enter cost of minor head followed by "✓" to accept the editing.***

Step-5: User can add more minor heads by repeating steps 3 & 4.

As soon as user clicks "✓" after entering cost of O&M head, programme adds cost of all O&M heads and the sum of all O&M head is written in the table showing year-wise O&M cost details heads on the left side of the screen.

- Step-6: To copy details to all the years ***click the button "Copy details for all years".***

O&M cost details for electricity generating equipments/systems have to be provided if electricity generation has been selected as another application of nuclear power plant.



5.3.3.4.2. Providing O&M cost as block estimate for all years

5.3.3.4.2(a) Providing O&M cost details as block estimate for nuclear power plant

In this option user has to provide routine O&M as well as refurbishment cost in terms of percentage of total capital cost of nuclear power plant. If electricity generation has been selected as another application of nuclear power plant, user has to provide routine O&M cost and refurbishment cost as percentage of capital cost of electricity generating equipment/systems. Figure 5-12 shows the screen for providing O&M cost as block estimate for nuclear power plant, which generates electricity along with supplying heat for hydrogen generation.

It may be noted that if user is entering O&M cost or refurbishment cost of nuclear power plant user shall consider cost of all components and systems required for all applications of nuclear power plant. If user is entering O&M cost or refurbishment cost of electricity generating equipments, then capital cost of equipments and systems required for electricity generation only shall be considered.

Click the option button "Use block estimate for annual O&M cost" followed by entering required information in relevant text boxes.

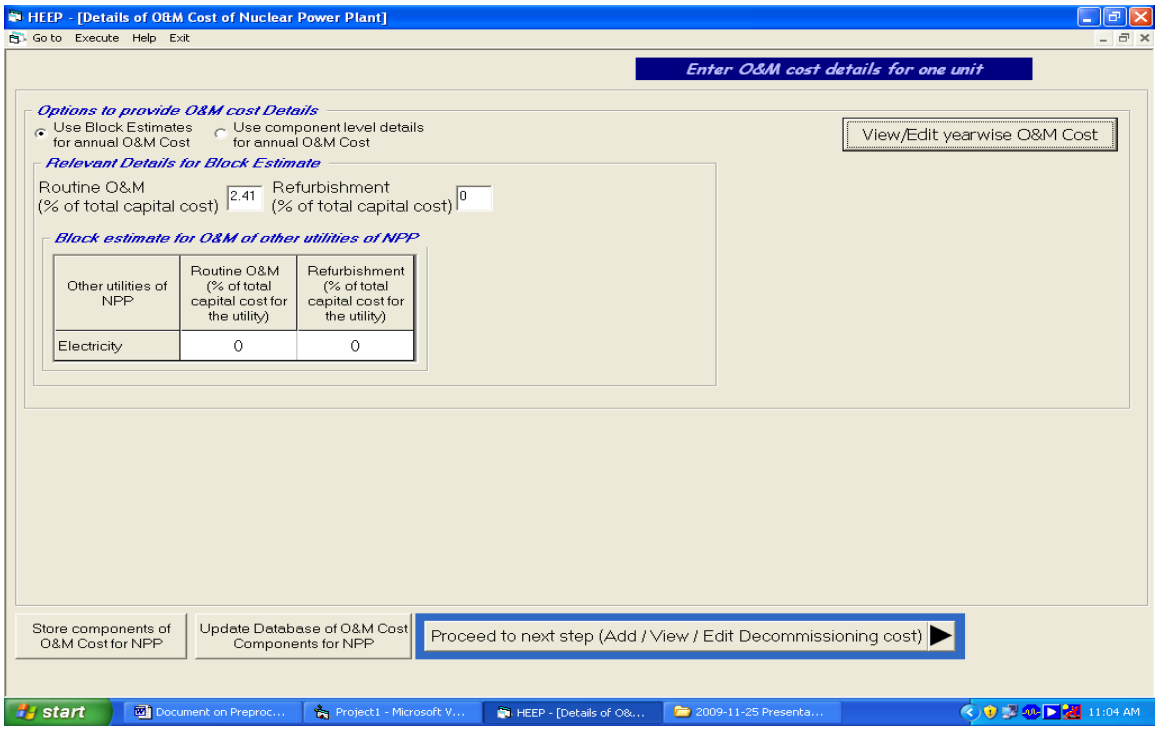


Figure 5-12: Window screen for entering O&M cost details for nuclear power plant.

5.3.3.4.2(b) Providing O&M cost details as block estimate for hydrogen generation and storage plan

If user wants to provide O&M cost for hydrogen generation and storage plant as block estimate, it is required to provide routine maintenance and refurbishment cost as percentage of total capital cost of hydrogen generation and storage plant. It is also required to provide information on the parameters listed in Table 5-31 affecting operating cost of hydrogen generation and storage.

Table 5-31: Parameters affecting operating cost of hydrogen generation and storage

Sl.	Parameter	Unit	Variable name	Remark
<u>For compressed gas storage option</u>				
1	Unit cost of thermal energy required	Cur/kWth-hr	H2SOMThER	Note-1
2	Unit cost of electricity required	Cur/kWe-hr	H2SOMEleR	Note-2
3	Unit cost of cooling water for compressor cooling	Cur/Million Ltrs	H2SOMCWR	
<u>For option to store in liquid form</u>				
1	Unit cost of thermal energy required	Cur/kWth-hr	H2SOMThER	Note-1
2	Unit cost of electricity required	Cur/kWe-hr	H2SOMEleR	Note-2
3	Unit cost of cooling water for compressor cooling	Cur/Million Ltrs	H2SOMCWR	

Sl.	Parameter	Unit	Variable name	Remark
For option to store in metal hydride form				
1	Unit cost of thermal energy required	Cur/kWth-hr	H2HydHeatR	Note-1
2	Unit cost of cooling water for compressor cooling	Cur/ Million Ltrs	H2HydCoolR	

Cur: Currency used for working
Note-1: Unit cost of thermal energy is required if the nuclear power plant and hydrogen generating and storage facility are isolated.
Note-2 Unit cost of electricity is required if nuclear power plant and hydrogen generation and storage facility isolated OR even if both the plants are co-located, but, if electricity requirement for hydrogen generation and storage is more than that generated by nuclear power plant.

Figure 5-13 shows the screenshot of the from requiring information on parameters affecting operating cost of hydrogen generation and storage facility.

Click button "Edit/Enter parameters affecting operating cost of H2 Generation & Storage" to view/enter required parameters followed by entering required information in relevant cells of the table

OR

Click the button "Hide parameters affecting operating cost of H2 Generation & Storage" to close the tables showing relevant parameters.

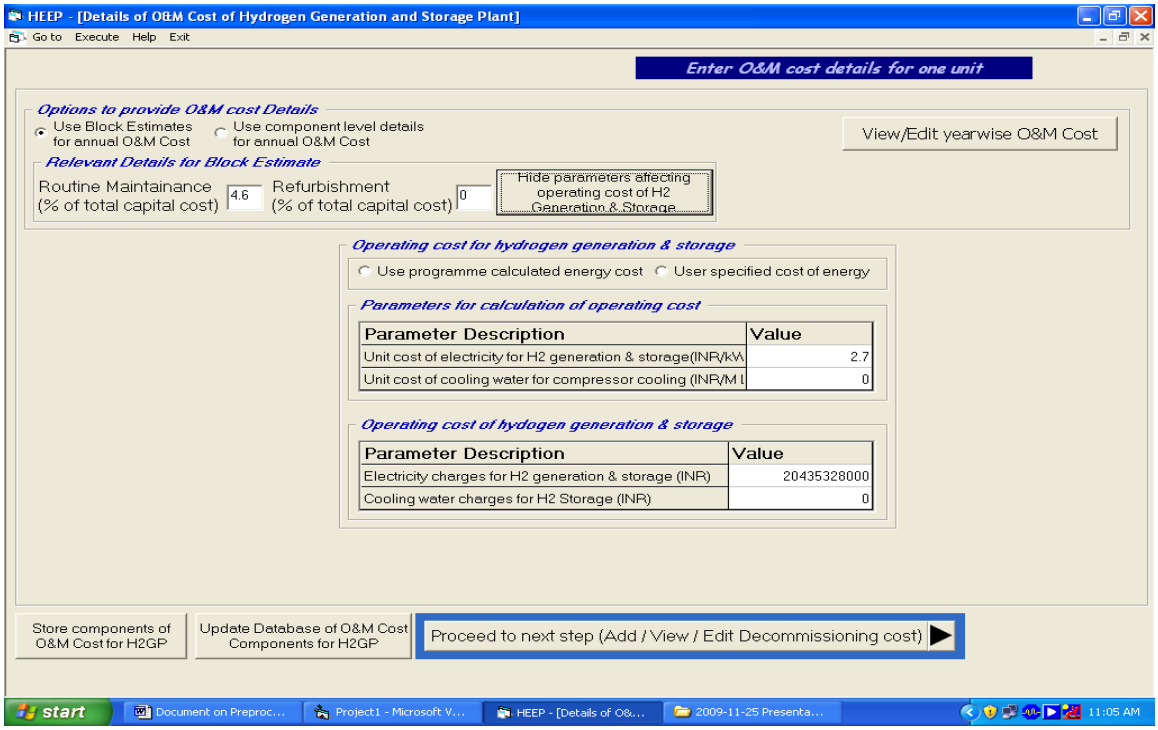


Figure 5-13: Window screen for providing information on parameters affecting cost of hydrogen generation and storage.

Once user provides these details, programme calculates operating cost of hydrogen generation and storage facility.

5.3.3.4.2(c) Providing O&M cost details as block estimate for hydrogen trnasportation

If user wants to provide O&M cost for hydrogen transportation facility as block estimate, it is required to provide routine maintenance and refurbishment cost as percentage of total capital cost of hydrogen transportation. It is also required to provide information on the parameters listed in Table 5-32 affecting operating cost of hydrogen transportation.

Table 5-32: Parameters affecting operating cost of hydrogen transportation

Sl.	Parameter	Unit	Variable name	Remark
For pipeline transportation				
1	Unit cost of electricity required for pumping of hydrogen	Cur/kWe-hr	H2TOMEleR	Note-1
For vehicle transportation				
1	Annual wages per driver	Cur	TransVehDriverR	
2	Cost of fuel	Cur/Ltr.	TransVehFuelR	

Cur: Currency used for working
Note-1 Unit cost of electricity is required if nuclear power plant and hydrogen generation and storage facility isolated OR even if both the plants are co-located, but, if electricity requirement for hydrogen generation, storage and transportation is more than that generated by nuclear power plant.

Figure 5-14 shows the screen for providing information on parameters affecting operating cost of hydrogen transportation through pipeline.

Click button "Edit/Enter parameters affecting operating cost of H2 Generation & Storage" to view/enter required parameters followed by entering required information in relevant cells of the table

OR

Click the button "Hide parameters affecting operating cost of H2 Generation & Storage" to close the tables showing relevant parameters.

Once user provides these details, programme calculates operating cost of hydrogen transpiration based on this information and technical details provided earlier.

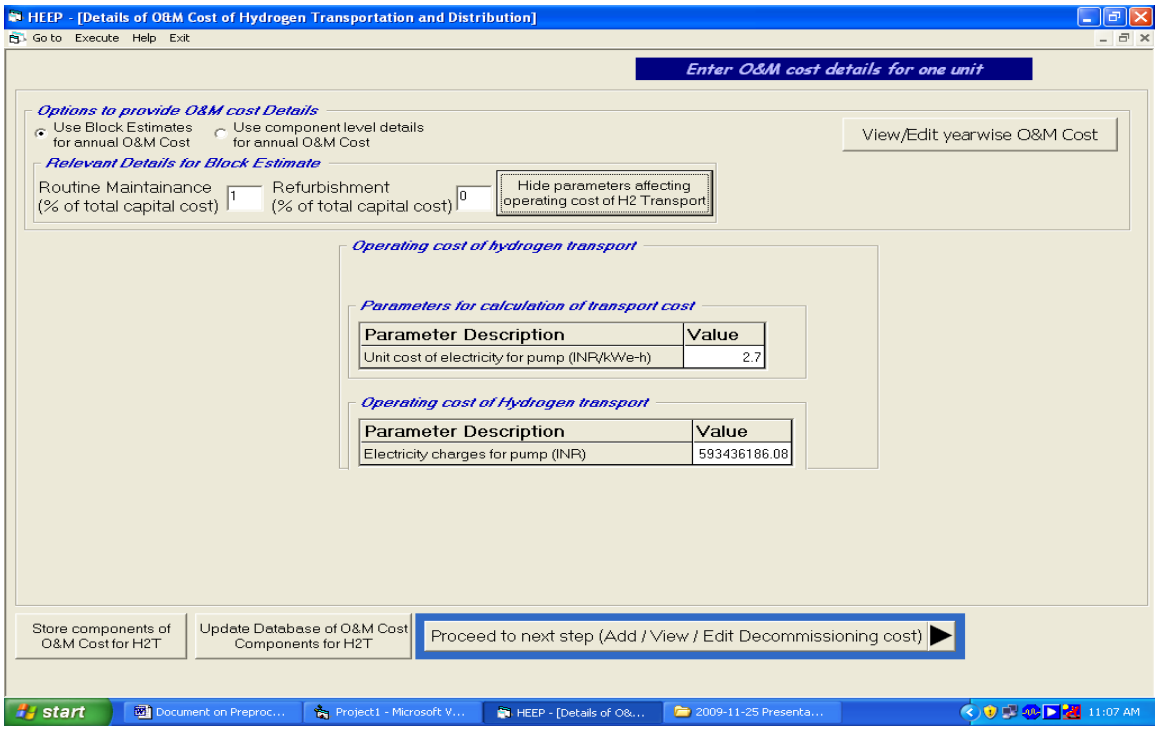


Figure 5-14: Window screen for providing information on parameters affecting cost of hydrogen transportation.

5.3.3.4.3. Next step after providing O&M cost

Click the button "Proceed to next step (Add / View / Edit Decommissioning cost)" to enter decommissioning cost details for nuclear power plant or hydrogen generation and storage plant or hydrogen transportation facility.

5.3.4. Providing Decommissioning cost details

After entering O&M cost details for the facilities generating and distributing nuclear hydrogen the next step is to provide details of decommissioning cost. User can open form/window for entering O&M cost details using any one of the following steps:

Click the button "Proceed to next step (Add / View / Edit Decommissioning cost)" to enter decommissioning cost details, if user has completed entering details of O&M cost.

OR

Click "Go to" – "Cost Components" from pull down menu followed by clicking "Add or Edit or View Details" of Decommissioning cost.

OR

- ***In the flowsheet window click the button "Cost Components of Nuclear Power Plant"*** (To go to flowsheet, from pull down menu ***click "Go to" – "Flowsheet"***) ***OR Click "Go to" – "Cost Components" from pull down menu***
- ***Click "Add or Edit or View Details" of Decommissioning cost.***

User has two options for entering decommissioning cost details:

(iii) Providing component level details for annual decommissioning cost
(iv) Providing decommissioning cost as block estimate for all years (% of total capital cost)

5.3.4.1. Providing component level details for annual decommissioning cost

In this option user has to provide component level details of decommissioning cost for each year during decommissioning period. User can consider various sub-heads as part of decommissioning cost.

Follow the steps given below to provide component level details for annual O&M cost.

- Step-1:

Click command button "View/Edit Year-wise Decommissioning Cost" to view/edit/add annual decommissioning cost *(Refer screenshots on next page)*

- Step-2: Frame showing year-wise total O&M cost will be visible. User cannot enter total O&M cost for the each year.

Click "Show/Edit Details" in the last column of the corresponding year to provide O&M cost details for the relevant year. *(Refer screenshots on next page)*

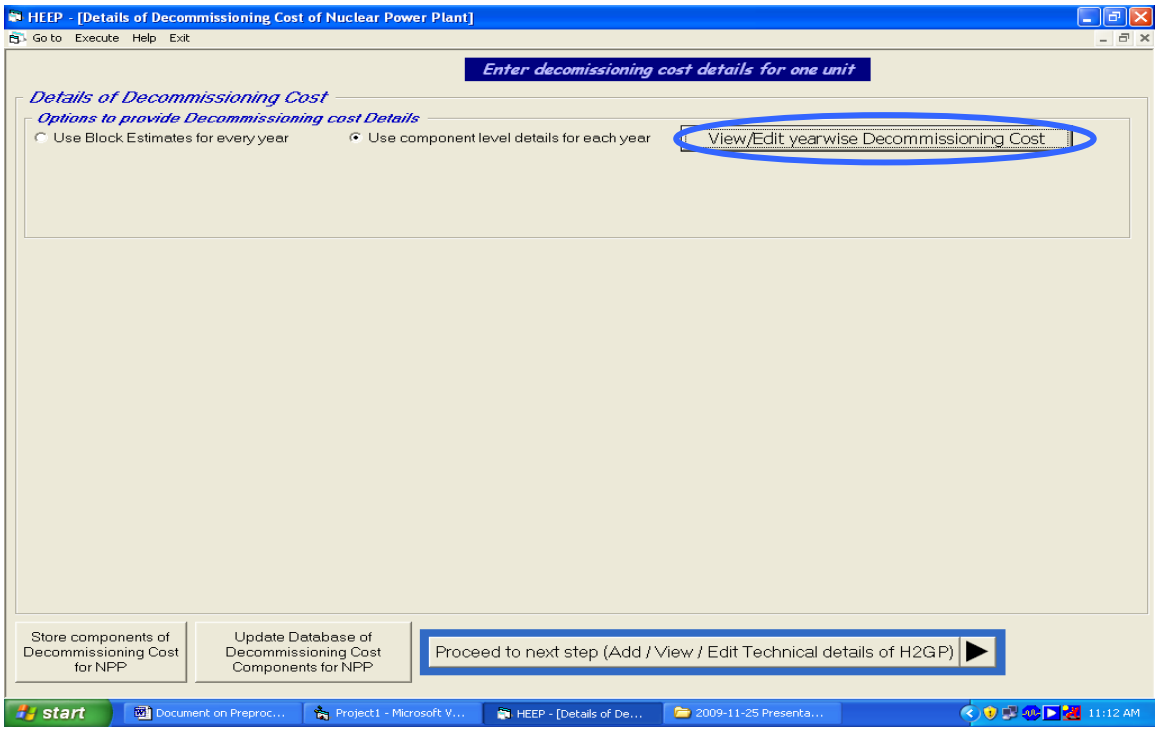
- Step-3: After clicking "Show/Edit Details" a frame for providing details of decommissioning cost heads will be visible. User will have to provide details of decommissioning cost head in this frame.

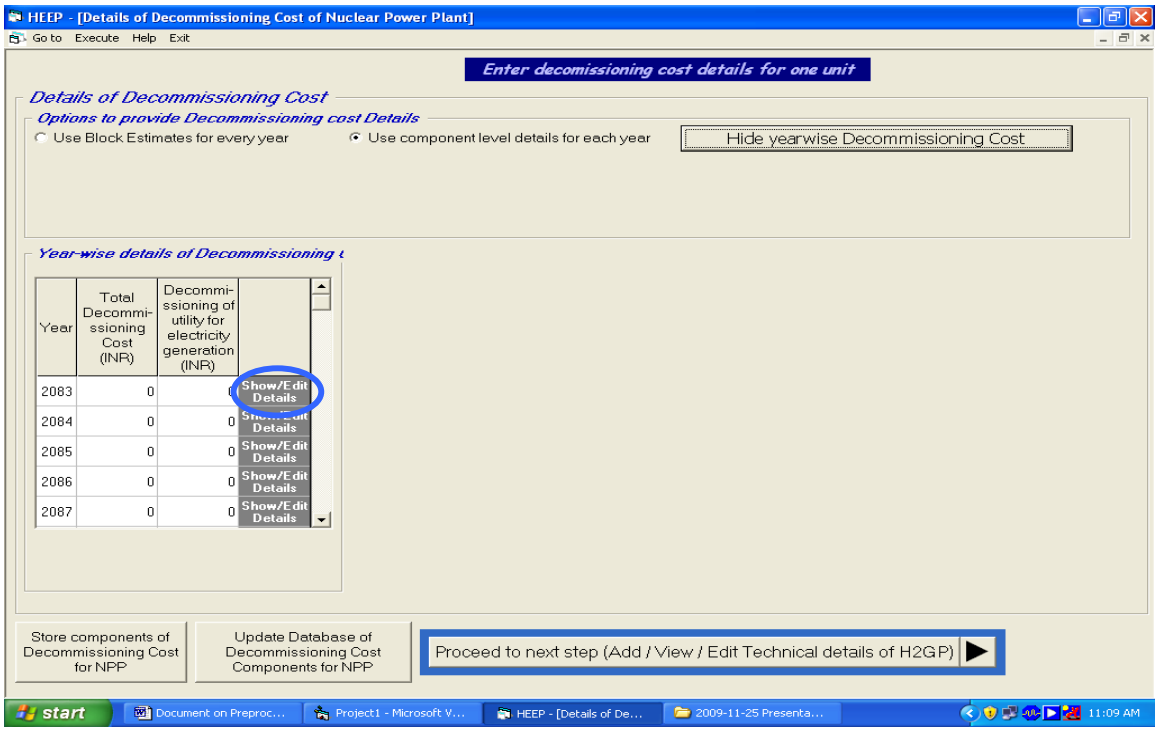
Click "Insert Decommissioning Head"

This will open a text box and two command buttons with signs "✓" and "X". ***Enter the description of the Decommissioning head in the text box and click "✓" to accept the description. Click "X" to cancel.***

- Step-4: User will have to enter cost of decommissioning head in this table.

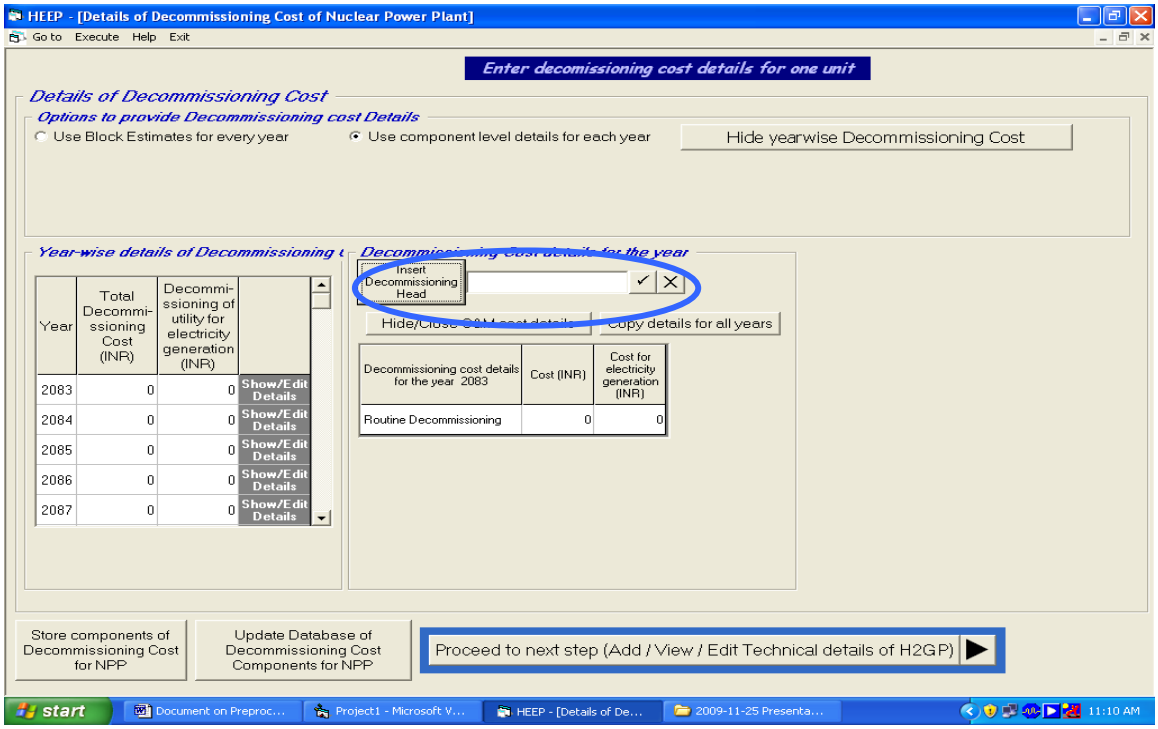
To enter cost of minor head ***click the cell corresponding to decommissioning head under column head "cost"*** and ***enter cost of minor head followed by "✓" to accept the editing.***



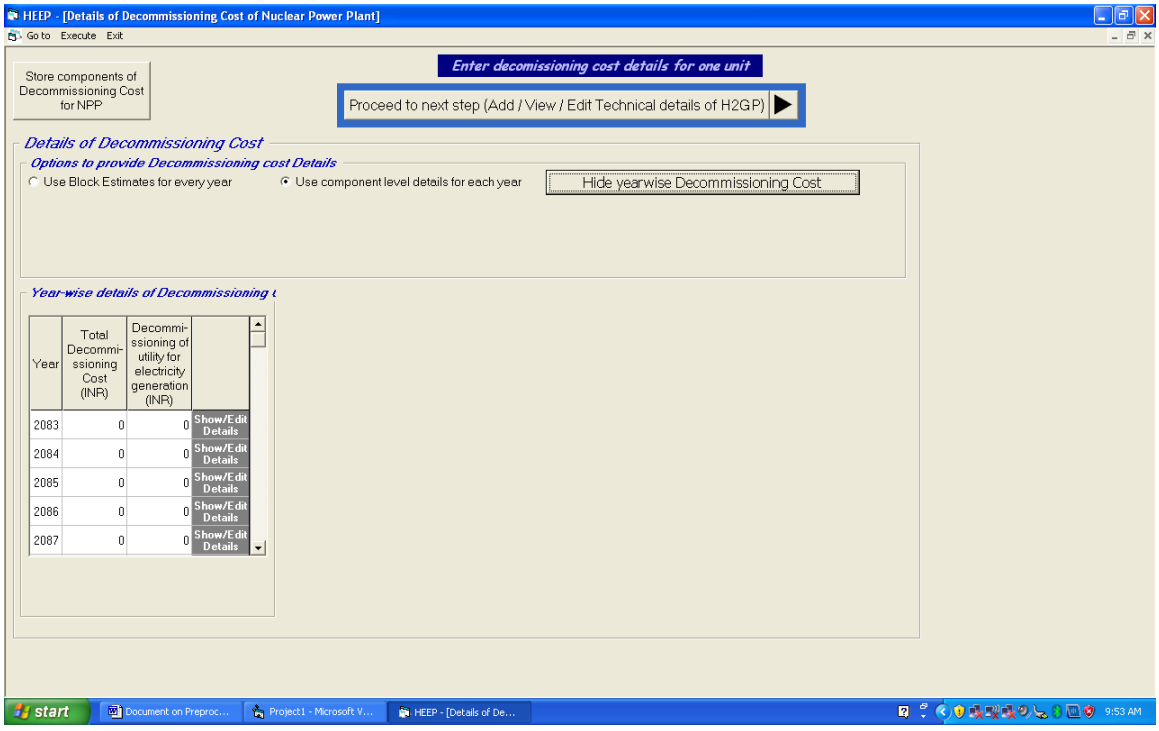


- Step-5: User can add more minor heads by repeating steps 3 & 4.

As soon as user clicks "✓" after entering cost of decommissioning head, programme adds cost of all decommissioning heads and the sum of all decommissioning heads is written in the table showing year-wise decommissioning cost details heads.



- Step-6: To copy details to all the years ***click the button "Copy details for all years".***



Decommissioning cost details for electricity generating equipments/systems have to be provided if electricity generation has been selected as another application of nuclear power plant.

5.3.4.2. Providing decommissioning cost as block estimate for all years

5.3.4.2.1. Providing decommissioning cost details as block estimate for nuclear power plant

In this option user has to provide routine decommissioning cost in terms of percentage of total capital cost of nuclear power plant. If electricity generation has been selected as another application of nuclear power plant, user has to provide routine decommissioning cost as percentage of capital cost of electricity generating equipment/systems. Figure 5-15 shows the screen for providing decommissioning cost as block estimate for nuclear power plant, which generates electricity along with supplying heat for hydrogen generation.

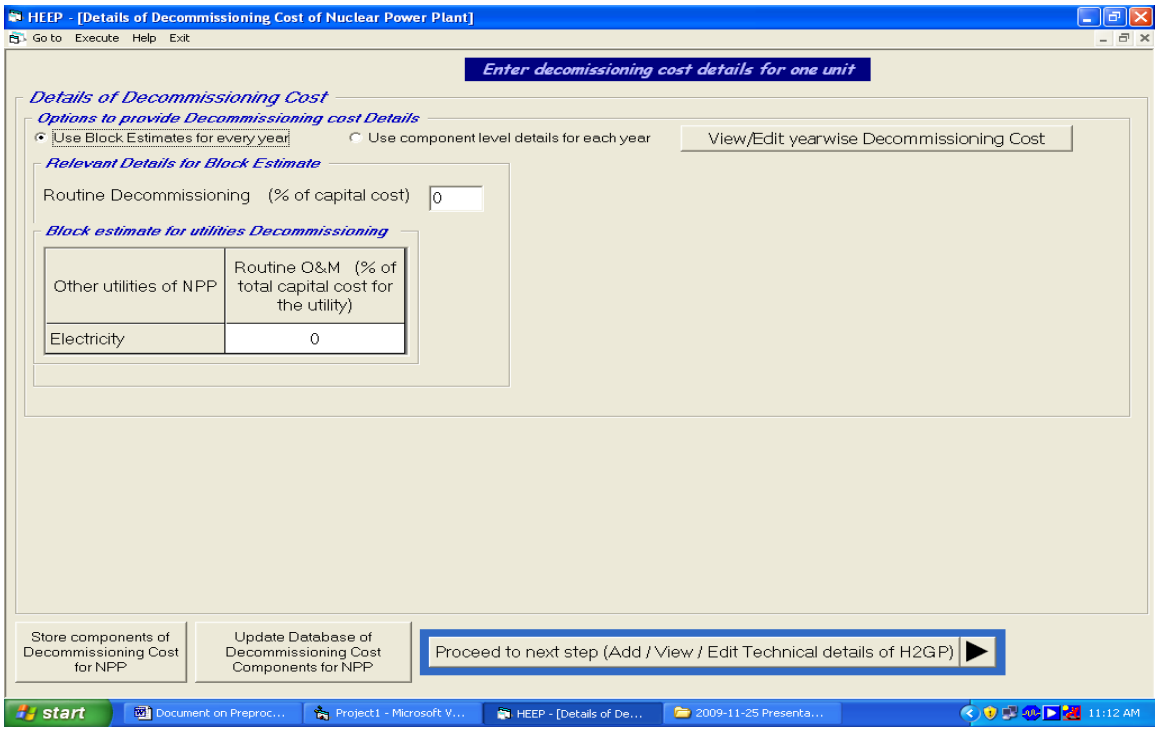


Figure 5-15: Window screen for entering decommissioning cost details for nuclear power plant generating electricity.

It may be noted that if user is entering decommissioning cost for nuclear power plant, user shall consider cost of all components and systems required for all applications of nuclear power plant. If user is entering O&M cost of electricity generating equipments, then capital cost of equipments and systems required for electricity generation only shall be considered.

Click the option button "Use block estimate for annual O&M cost" followed by entering required information in relevant text boxes.

5.3.4.2.2. Providing decommissioning cost details as block estimate for hydrogen generation and storage plant or hydrogen transportation and distribution facility

If user wants to provide decommissioning cost for hydrogen generation and storage plant or hydrogen transportation and distribution facility as block estimate, it is required to provide routine decommissioning cost as percentage of total capital cost of corresponding plant or facility.

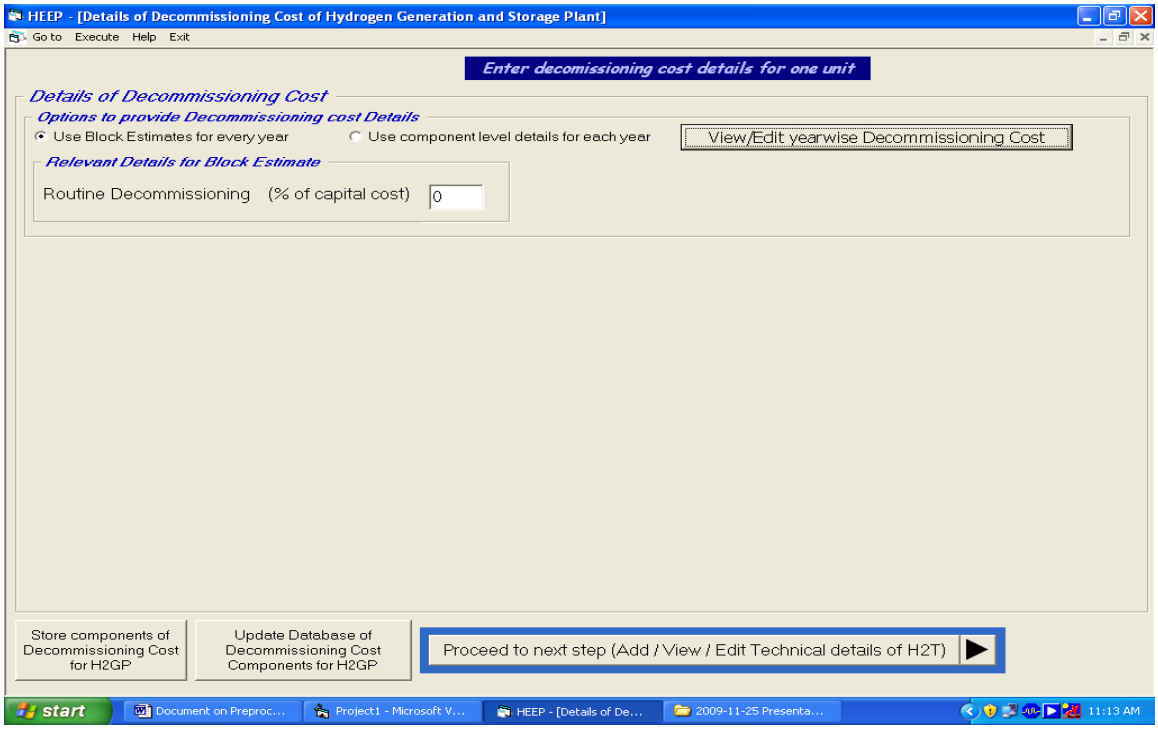


Figure 5-16: Window screen for providing information on parameters affecting cost of hydrogen generation and storage.

5.3.4.3. Next step after providing Decommissioning cost

Click the button "Proceed to next step (Add / View / Edit Technical Details of H2GP)" if user has completed entering decommissioning cost details for nuclear power plant **OR** ***Click the button "Proceed to next step (Add / View / Edit Technical Details of H2T***)" if user has completed entering decommissioning cost details for hydrogen generation and storage plant **OR** ***Click the button "Proceed to next step (Execute***)" if user has completed entering decommissioning cost details for hydrogen transportation.

References

[1] Wade A. Amos, “Cost of Storing and Transporting Hydrogen”, National Renewable Energy Laboratory, NREL/TP-570-25106, November 1998