


The background of the slide is an aerial photograph of Lausanne, Switzerland. It shows the city's buildings, green spaces, and the surrounding Lake Geneva under a blue sky with scattered clouds. A red semi-transparent rectangle is overlaid on the right side of the image, containing the title and subtitle.

Tutorial of Economic Analysis

Process development – CHE 459
Du Wen

April 2025

Class 5: Order-of-magnitude estimate 
Normally, it requires only a block flow diagram.

Class 4: Study estimate 
Based on the process flow diagram. Costs from generalized charts.

Class 3: Preliminary estimate
Based on PFD. Includes vessel sketches for major equipment, preliminary plot plan, and elevation diagram.

Class 2: Definitive estimate
Final PFD, vessel sketches, plot plan, and elevation diagrams, utility balances, and a preliminary piping and instrumentation diagram (P&ID).

Class 1: Detailed estimate
Final PFD and P&ID, vessel sketches, utility balances, plot plan and elevation diagrams, and piping isometrics. All diagrams are required to complete the construction of the plant if it is built.

Class	Complete definition	Purpose of estimation	Methodology
5	0-2%	Screening or Feasibility	Stochastic or Judgment
4	1-15%	Concept Study or Feasibility	Primarily Stochastic
3	10-40%	Budget, authorization or Control	Mixed but Primarily Stochastic
2	30-70%	Control or Tender	Primarily Deterministic
1	50-100%	Check Estimate or Tender	Deterministic

Error of class 1: +6% ~ -4%

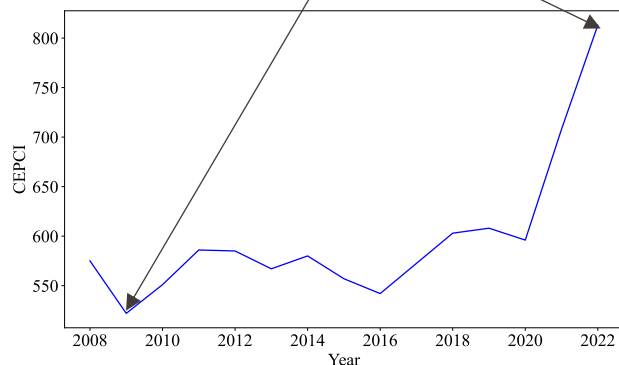
Error of class 4&5: +40% ~ -25%

$$\log_{10} C_P^0 = K_1 + K_2 \log_{10} S_a + K_3 (\log_{10} S_a)^2 \quad \text{Equipment cost attribute (size)}$$

↓ Purchased cost at the year in the book (CEPCI=397, 2001)

$$\frac{C_{Pa}^0}{C_{P_{ref}}^0} = \left(\frac{S_a}{S_{ref}} \right)^n \frac{I_{2022}}{I_{2009}} \quad \text{Size exponent, 0.6}$$

Cost index - Chemical Engineering Plant Cost Index (CEPCI)

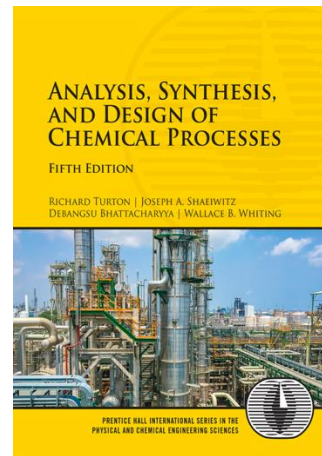


$$\frac{I_{2022}}{I_{2009}} = \frac{813}{522} = 1.56$$

When you spend money is important

Note:

The calculation equation of bare module cost will change according to different types of equipment.
You can find all the information in this book.



$$\text{Bare module cost: } C_{BM} = C_P^0 F_{BM} = C_P^0 (B_1 + B_2 F_M F_P) = C_P^0 F_{BM} F_P F_T \quad \text{Temperature factor}$$

Bare module cost factor Material factor Pressure factor

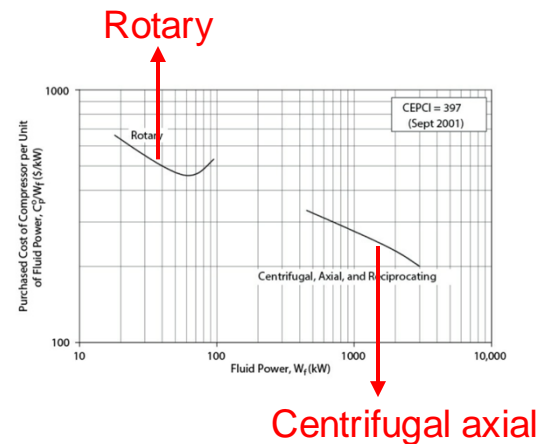
Case Study: Compressor

$$\log_{10} C_P^0 = K_1 + K_2 \log_{10} P + K_3 (\log_{10} P)^2 \longrightarrow \text{Equipment cost attribute, fluid power, kW Achieved in ASPEN.}$$

Purchase cost of the equipment, at ambient operating pressure and using carbon steel construction.

Table A.1 Equipment Cost Data to Be Used with Equation (A.1)

Equipment Type	Equipment Description	K_1	K_2	K_3	Capacity, Units	Min Size	Max Size
Compressors	Centrifugal, axial, and reciprocating	2.2897	1.3604	-0.1027	Fluid power, kW	450	3000
	Rotary	5.0355	-1.8002	0.8253	Fluid power, kW	18	950



Be careful with the range and unit

Pressure factor $\leftarrow \log_{10} F_P = C_1 + C_2 \log_{10} P + C_3 (\log_{10} P)^2$

Table A.2 Pressure Factors for Process Equipment

Go to page 1297

Equipment Type	Equipment Description	C_1	C_2	C_3	Pressure Range (barg)
Compressors	Centrifugal, axial, rotary,	0	0	0	—
Pumps	Reciprocating	0	0	0	$P < 10$
		-0.245382	0.259016	-0.01363	$10 < P < 100$
	Positive displacement	0	0	0	$P < 10$
		-0.245382	0.259016	-0.01363	$10 < P < 100$
	Centrifugal	0	0	0	$P < 10$
		-0.3935	0.3957	-0.00226	$10 < P < 100$

Note:

The pressure factor of compressors is 1;
For other equipment, such as pumps, be careful with the pressure range.

$$C_{BM} = C_P^0 F_{BM} = C_P^0 (B_1 + B_2 F_M F_P) \quad \text{Equations depend on the type of equipment}$$

Table A.4 Constants for Bare Module Factor to Be Used in Equation (A.4)

Equipment Type	Equipment Description	B_1	B_2
Heat exchangers	Double pipe, multiple pipe, scraped wall, and spiral tube	1.74	1.55
	Fixed tube sheet, floating head, U-tube, bayonet, kettle reboiler, and Teflon tube	1.63	1.66
	Air cooler, spiral plate, and flat plate	0.96	1.21
Process vessels	Horizontal	1.49	1.52
	Vertical (including towers)	2.25	1.82
Pumps	Reciprocating	1.89	1.35
	Positive displacement	1.89	1.35

Table A.5 Equations for Bare Module Cost for Equipment Not Covered by Tables A.3 and A.4

Equipment Type	Equation for Bare Module Cost
Compressors and blowers without drives	$C_{BM} = C_P^0 F_{BM}$
Drives for compressors and blowers	$C_{BM} = C_P^0 F_{BM}$
Evaporators and vaporizers	$C_{BM} = C_P^0 F_{BM} F_P$
Fans with electric drives	$C_{BM} = C_P^0 F_{BM} F_P$
Fired heaters and furnaces	$C_{BM} = C_P^0 F_{BM} F_P F_T$

$$C_{BM} = C_P^0 F_{BM} = C_P^0 (B_1 + B_2 F_M F_P)$$

Equations depend on the type of equipment

Table A.6 Identification of Material Factors for Equipment Listed in Table A.5 to Be Used with Figure A.19

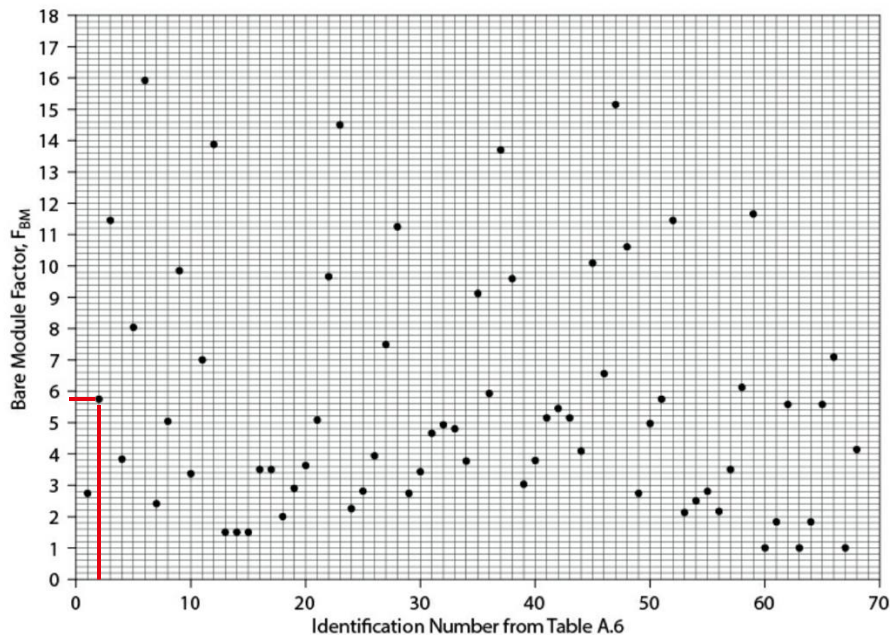
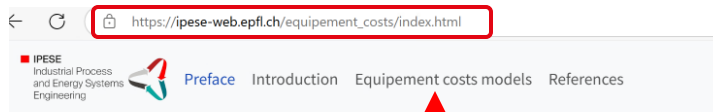


Figure A.19 Bare Module Factors for Equipment in Table

Identification Number	Equipment Type	Equipment Description	Material of Construction
1	Compressors/blowers	Centrifugal compressor or blower	CS
2	$F_{BM}=5.75$	Centrifugal compressor or blower	SS
3		Centrifugal compressor or blower	Ni alloy
4		Axial compressor or blower	CS
5		Axial	SS



Get access to the website: https://ipese-web.epfl.ch/equipement_costs/index.html.

Preface

AUTHOR

Du Wen, François Maréchal

Edit

This Quarto book will give an introduction of how we connect all resources in FM's lab.

All relevant information of each process unit will be put in one folder with the name of the unit being the name of the folder, such as:

- **index.qmd**: It is the documentation of the process using markdown text.
- **References**: A reference.bib file which includes references of model development and relevant data.
- **./Model**: A folder that includes the model of the unit :
 - Model File can be with different formats:
 - **.asp**: Aspen format
 - **.xls**: Xls format
 - **.lua**: ET.lua format of osmose.lua
 - **Input.csv**: Input of the model with the following format:
 - **"from"**: command that accesses the value in osmose.
 - **"to"**: command that allows to transfer the value to Input.csv.
 - **"unit"**: physical unit of the value transferred.
 - **"Value"**: value transferred.
 - **Output.csv**: Output of the model with the following format:
 - **"from"**: command that accesses the the location in model and extract the value after the model execution.
 - **"to"**: command that allows to transfer the value to Output.csv.
 - **"unit"**: physical unit of the value transferred.
 - **"Value"**: value resulting from the model execution.
 - **Script**: It is a Python script with the following functions:
 - **create index.qmd**: If there is no such a file, create one with a fixed format.
 - **execute ET.lua**: Find the location of the ET file, create a frontend.lua to include ET.lua, execute OSMOSE, read the results in .json.

← ↻ 🔒 https://ipese-web.epfl.ch/equipment_costs/equipment_costs/index.html 🔍 ⭐ ⚙ ...

■ IPES
Industrial Process
and Energy Systems
Engineering

Preface Introduction **Equipment costs models** References 🔍

Equipment costs models

Categories
All (2)

Edit

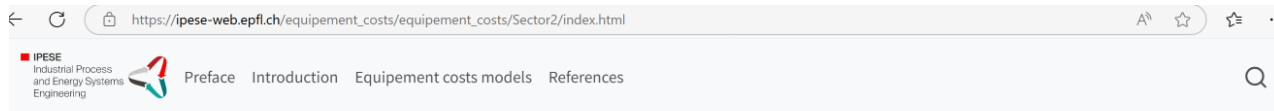
In each industrial sector, it contains relevant process units.

🔍 Filter

Industrial sector 1
Process units for industrial sector 1

Industrial sector 2
Process units for industrial sector 2

Find the equipment cost library here.



Industrial sector 2

Categories

All (144)

Edit

Process units for industrial sector 2

Filter

cost_O2separator

Add here a description of the equipment, define the reference size, the function of the activity modeled by the process unit and the assumptions.

cost_SteamBoilers

Add here a description of the equipment, define the reference size, the function of the activity modeled by the process unit and the assumptions.

cost_LiquidRadialExpanderS

Add here a description of the equipment, define the reference size, the function of the activity modeled by the process unit and the assumptions.

cost_FuelCell_SOFC

cost_PelsterCompressor_a

cost_PlanarSOFC_leni

We put the underlying code here. You can look at the documentation, inputs, and outputs.


The screenshot shows a web browser window with the URL https://ipese-web.epfl.ch/equipment_costs/equipment_costs/Sector2/index.html. The page header includes the IPSE logo and navigation links: Preface, Introduction, Equipment costs models, and References. A search bar at the top right contains the text 'compressor'. Below the search bar, a grid of six equipment cost entries is displayed. Each entry has a title, a description, and a reference size. The entries are:


- cost_PelsterCompressor_axial
- cost_compressor_reciprocating
- cost_compressor_centrifugal
- cost_compressor_rotary
- cost_FuelCompressor_axial
- cost_compressor_axial

Red arrows point from the search bar to the 'cost_compressor_centrifugal' and 'cost_compressor_axial' entries, highlighting the search results.


You can search for the equipment.

The equipment subcategory is shown in the name.

 IPESE
Industrial Process
and Energy Systems
Engineering



[Preface](#) [Introduction](#) [Equipment costs models](#) [References](#)



Edit

For more details, you can check the description.

Maziar Kermani

Versioning

2017-07-24 V1: update based on latest data from the reference

Input parameters

`cost_compressor_axial(shaftpower, material='CS')`

Required inputs

Code

▼ Show/hide code for vertical vessel

```
from equipment_costs import cost_compressor_axial

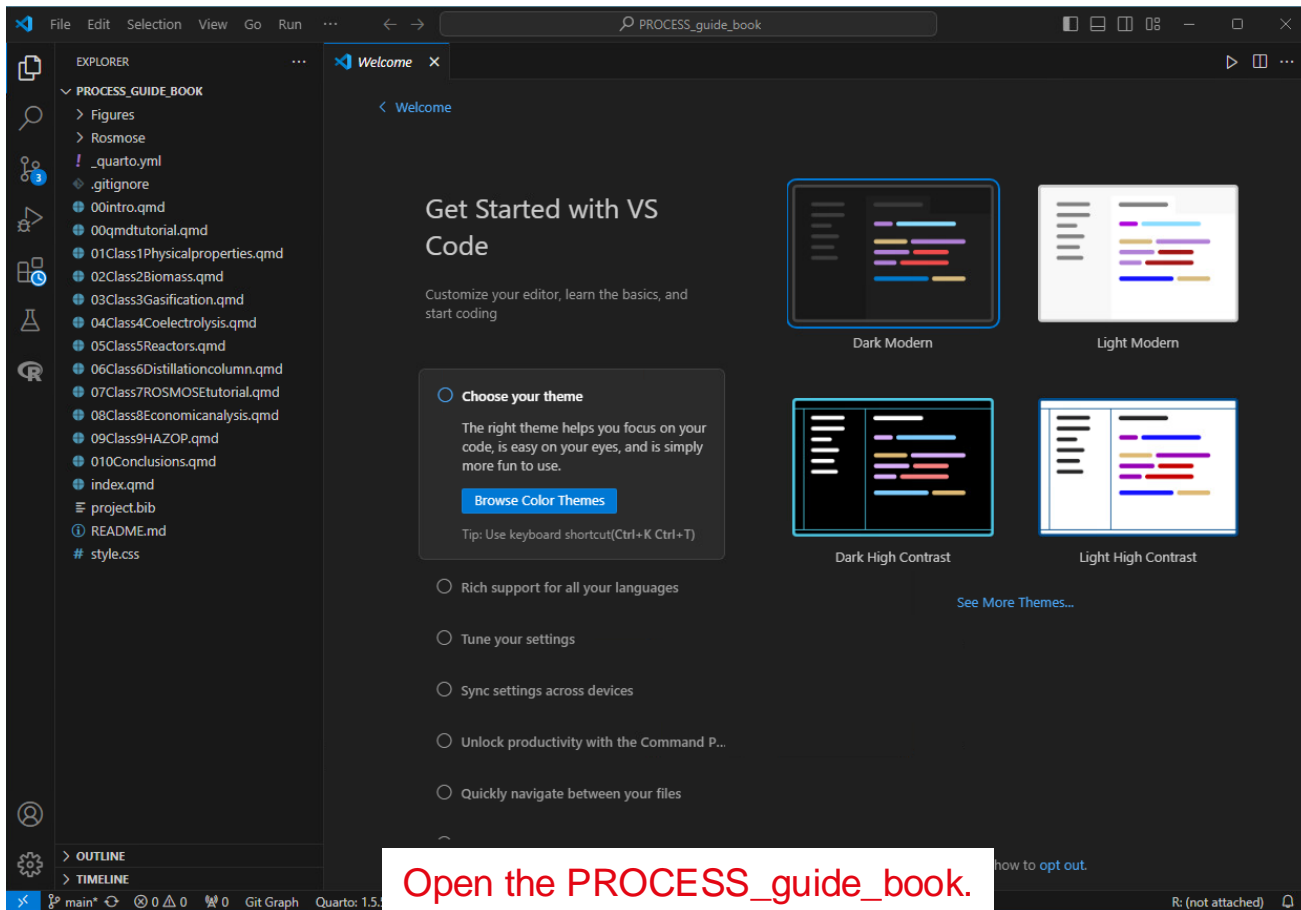
Cost_BM, Cost_TM, Cost_GR = cost_compressor_axial(shaftpower, material='CS')
print(Cost_BM, Cost_TM, Cost_GR)
```

Copy and paste

...

► Details

Equipment Cost Calculation - Overview



Open the PROCESS_guide_book.

Equipment Cost Calculation - Overview

The screenshot shows the Visual Studio Code interface with the Extensions Marketplace open. The search bar contains 'quarto'. The 'Quarto' extension by quarto.org is selected, showing its details. The extension is version v1.119.0, has 189,425 downloads, and a 5-star rating from 18 reviews. It is described as an 'Extension for the Quarto scientific and technical publishing system.' The 'quarto-vscode' extension is also highlighted, with a description: 'VS Code extension for the Quarto scientific and technical publishing system. This extension provides language support for Quarto .qmd files, including:'. A list of features is provided, such as 'Render command with integrated preview pane', 'Syntax highlighting for markdown and embedded languages', and 'Completion for embedded languages (e.g. Python, R, Julia, LaTeX, etc.)'. The 'Installation' section states: 'The easiest way to install is directly from within VS Code (search extensions for "quarto").' A red text box at the bottom of the screenshot says 'Install the Quarto extension.'

File Edit Selection View Go Run ... PROCESS_guide_book

EXTENSIONS: MARKETPLACE

quarto

Quarto v1.119.0
Extension for the Quarto sci...
quarto.org | 189,425 | ★★★★★(18)
Extension for the Quarto scientific and technical publishing system.
Install Auto Update

quarto-vscode

VS Code extension for the Quarto scientific and technical publishing system. This extension provides language support for Quarto .qmd files, including:

- Render command with integrated preview pane
- Syntax highlighting for markdown and embedded languages
- Completion for embedded languages (e.g. Python, R, Julia, LaTeX, etc.)
- Completion and diagnostics for project files and document/cell options
- Completion for citations and cross references
- Commands and key-bindings for running cells and selected line(s)
- Automatic navigation to render errors for Jupyter, Knitr, and YAML
- Live preview for embedded Mermaid and Graphviz diagrams
- Assist panel for contextual help, image preview, and math preview
- Code snippets for common markdown constructs
- Code folding and document outline for navigation within documents
- Workspace symbol provider for navigation across project files

Installation

The easiest way to install is directly from within VS Code (search extensions for "quarto").

Categories

- Programming Languages
- Data Science
- Machine Learning
- Notebooks

Resources

- Marketplace
- Issues
- Repository
- License
- Quarto

More Info

Published 2022-02-10, 19:32:08

Last released 2025-03-21, 20:08:02

Last updated 2025-04-02, 16:29:58

Identifier quarto.quarto

main* 0 0 0 Git Graph

R: (not attached)

Equipment Cost Calculation - Overview

File Edit Selection View Go Run ...

PROCESS_guide_book

EXTENSIONS: MARKETPLACE

jupyter

Jupyter 89.9M ★ 2.5
Jupyter notebook support, i...
Microsoft [Install](#)

Jupyter Key... 70.9M ★ 4
Jupyter keymaps for notebo...
Microsoft [Install](#)

Jupyter Slide ... 51.2M ★ 5
Jupyter Slide Show support ...
Microsoft [Install](#)

Jupyter Cell T... 51.3M ★ 5
Jupyter Cell Tags support fo...
Microsoft [Install](#)

Jupyter Not... 69.9M ★ 2.5
Renderers for Jupyter Noteb...
Microsoft [Install](#)

Jupyter (dep... 809K ★ 3.5
Data Science with Jupyter o...
Don Jayamanne [Install](#)

Jupyter Pow... 590K ★ 4.5
Experimental features for Ju...
Microsoft [Install](#)

VS Code Jup... 719K ★ 3.5
An easy to use extension for...
jithurjacob [Install](#)

jupyter-noteb... 161K ★ 1
Runs jupyter notebooks in v...
Sam Helms [Install](#)

Jupyter Theme 72K ★ 5
A colour theme based arou...
SamCoding [Install](#)

Jupyter v2025.3.0
Microsoft [microsoft.com](#) | 89,901,212 | ★★★★★ (331)
Jupyter notebook support, interactive programming and computing that supports Intellis...
[Install](#) ✓ Auto Update

DETAILS FEATURES CHANGELOG

Extension Pack (4)

Jupyter Keymap
Jupyter keymaps for notebooks
Microsoft [Install](#)

Jupyter Notebook Renderers
Renderers for Jupyter Notebooks (with plotly...
Microsoft [Install](#)

Categories

- Extension Packs
- Data Science
- Machine Learning
- Visualization
- Notebooks

Resources

- Marketplace
- Issues
- Repository
- License
- Microsoft

More Info

Published	2020-11-11, 20:14:18
Last released	2025-04-01, 23:42:13
Identifier	ms-

A Visual Studio Code extension that provides basic notebook support for language kernels that are supported in Jupyter Notebooks today, and allows any Python environment to be used as a Jupyter kernel. This is **NOT a Jupyter kernel**--you must have Python environment in which you've installed the Jupyter package, though many language kernels will work with no modification. To enable advanced features, modifications may be needed in the VS Code language extensions.

python extension have incompatible shared dependency...

R: (not attached)

Install the Jupyter extension.

Equipment Cost Calculation - Overview

Python - m pip install --extra-index-url=https://ipse-internal.epfl.ch/registry/pypi equipment_costs

PROBLEMS OUTPUT DEBUG CONSOLE **TERMINAL** PORTS

```
PS C:\Users\dwen\Desktop\PROCESS_guide_book> python -m pip install --extra-index-url=https://ipse-internal.epfl.ch/registry/pypi equipment_costs
```

Install equipment_costs package using Terminal.
Use EPFL network to install the package.

Equipment Cost Calculation - Overview

The screenshot displays the Visual Studio Code interface. The Explorer panel on the left shows a project named 'PROCESS_guide_book' with a file tree including 'Figures', 'Rosmose', 'frontend_MER_files', 'frontend_TotalCost_files', 'ipese', 'model', 'result', 'temp', 'frontend_MER_20MW.html', 'frontend_MER_30MW.html', 'frontend_MER.html', 'frontend_MER.qmd', 'frontend_TotalCost.html', 'frontend_TotalCost.qmd', 'report.rmd', '_quarto.yml', '.gitignore', '00intro.qmd', '00qmdtutorial.qmd', '01Class1Physicalproperties.qmd', '02Class2Biomass.qmd', '03Class3Gasification.qmd', '04Class4Coelectrolysis.qmd', '05Class5Reactors.qmd', '06Class6Distillationcolumn.qmd', '07Class7ROSMOSEtutorial.qmd', '08Class8Economicanalysis.qmd', '09Class9HAZOP.qmd', '010Conclusions.qmd', 'equipment cost.qmd', 'index.qmd', and 'project.bib'. The 'equipment cost.qmd' file is selected and highlighted in blue.

The main editor area shows the 'equipment cost.qmd' file, which contains a Python code chunk. The code is as follows:

```
1 {python}
2 from equipment_costs import cost_compressor_axial
3
4 Cost_BM, Cost_TM, Cost_GR = cost_compressor_axial(500)
5 print(Cost_BM, Cost_TM, Cost_GR)
6
```

The terminal window at the bottom shows the output of the code execution, including the installation of numpy and equipment_costs packages. The output includes the following text:

```
Downloading numpy-2.2.4-cp311-win_amd64.whl.metadata (60 kB)
60.8/60.8 kB 538.3 kB/s eta 0:00:00
Downloading numpy-2.2.4-cp311-win_amd64.whl (12.9 MB)
12.9/12.9 MB 32.7 MB/s eta 0:00:00
Installing collected packages: numpy, equipment_costs
WARNING: Failed to write executable - trying to use .deleteme logic
ERROR: Could not install packages due to an OSError: [WinError 2] The system cannot find the file specified: 'C:\\Python311\\Scripts\\f2py.exe' -> 'C:\\Python311\\Scripts\\f2py.exe.deleteme'

[notice] A new release of pip is available: 24.0 -> 25.0.1
[notice] To update pip, run: python -m pip install --upgrade pip
PS C:\Users\Wen\Documents\PROCESS_guide_book>
```

A red box highlights the Python code chunk in the editor. A red arrow points from the text 'Create a Python chunk.' to the code chunk.

Equipment Cost Calculation - Overview

The screenshot displays the Visual Studio Code interface with a Python script named `equipment cost.qmd` open. The script contains the following code:

```
1 {python}  
2 from equipment_costs import  
3   cost_compressor_axial  
4   Cost_BM, Cost_TM, Cost_GR =  
5   cost_compressor_axial(500)  
6   print(Cost_BM, Cost_TM, Cost_GR)  
7
```

A red arrow points to the 'Run Cell' button (a play icon) above line 2. A dialog box titled 'Visual Studio Code' is displayed, stating: 'Running cells with 'Python 3.11.9' requires the ipykernel package.' The dialog has buttons for 'Install', 'Change Kernel', 'More Info', and 'Cancel'. The 'Install' button is highlighted.

The terminal at the bottom shows the following output:

```
Downloading numpy-2.2.4-cp311-win_amd64.whl.metadata (60 kB)  
60.8/60.8 kB 538.3 kB/s eta 0:00:00  
Downloading numpy-2.2.4-cp311-win_amd64.whl (12.9 MB)  
12.9/12.9 MB 32.7 MB/s eta 0:00:00  
Installing collected packages: numpy, equipment_costs  
WARNING: Failed to write executable - trying to use .delete logic  
ERROR: Could not install packages due to an OSError: [WinError 2] The system cannot find the file specified: 'C:\\Python311\\Scripts\\f2py.exe' -> 'C:\\Python311\\Scripts\\f2py.exe.delete logic'  
[notice] A new release of pip is available: 24.0 -> 25.0.1  
[notice] PS C:\\Use
```

A red text box at the bottom of the terminal area says: 'Install one more package.'

Equipment Cost Calculation - Overview

The screenshot shows a Jupyter Notebook interface with a dark theme. The left sidebar displays the file explorer with a tree view of the project structure, including folders like 'PROCESS_GUIDE_BOOK' and 'figures', and files like 'equipment_cost.qmd'. The main area shows a code cell with the following Python code:

```
1 {python}
2 from equipment_costs import
3   cost_compressor_axial
4
5 Cost_BM, Cost_TM, Cost_GR =
6   cost_compressor_axial(500)
7 print(Cost_BM, Cost_TM, Cost_GR)
```

The right sidebar shows the interactive console with a traceback error message:

```
ModuleNotFoundError: No module named 'equipment_costs'
```

Below the code cell, the terminal window is open, showing the command to install the package:

```
Python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi equipment_costs
```

The terminal output shows the installation progress and a warning message:

```
WARNING: Failed to write executable - trying to use .delete logic
ERROR: Could not install packages due to an OSError: [WinError 2] The system cannot find the file specified: 'C:\Python311\Scripts\python.exe' -> 'C:\Python311\Scripts\python.exe.delete'
```

A red arrow points from the terminal output to the command line, indicating the need to reinstall the package.

Reinstall the equipment_costs package using Terminal.

Equipment Cost Calculation - Compressor

The screenshot displays a JupyterLab environment with a dark theme. On the left, the 'EXPLORER' sidebar shows a file tree for 'PROCESS_GUIDE_BOOK'. The main editor area contains a code cell named 'equipment cost.qmd' with the following Python code:

```
1 {python}  
2 from equipment_costs import  
3   cost_compressor_axial  
4  
5 Cost_BM, Cost_TM, Cost_GR =  
6   cost_compressor_axial(500)  
7  
8 print(Cost_BM, Cost_TM, Cost_GR)  
9 ...
```

Below the code cell, the 'Interactive-1' console shows the execution output, which is highlighted with a red box:

```
✓ from equipment_costs import  
... 956687.2845843866 1128890.9958095762 1463731.5454141
```

At the bottom, the 'TERMINAL' panel shows the command prompt output for the command `python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi equipment_costs`. The output is also highlighted with a red box:

```
PS C:\Users\dwen\Desktop\PROCESS_guide_book> python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi equipment_costs  
Looking in indexes: https://pypi.org/simple, https://ipese-internal.epfl.ch/registry/pypi  
Collecting equipment_costs  
  Downloading https://ipese-internal.epfl.ch/registry/pypi/packages/equipment_costs-0.0.2-py3-none-any.whl (436 kB)  
    436.4/436.4 kB 9.1 MB/s eta 0:00:00  
Requirement already satisfied: numpy<3.0.0,>=2.0.0 in c:\python311\lib\site-packages (from equipment_costs) (2.2.4)  
Installing collected packages: equipment_costs  
Successfully installed equipment_costs-0.0.2
```

The status bar at the bottom indicates the current file is 'main*', the editor is at 'Ln 5, Col 4', and the application is 'Quarto: 1.5.56'.

Equipment Cost Calculation - Compressor

The screenshot displays a Jupyter Notebook environment with the following components:

- EXPLORER:** A file browser on the left showing a project structure for 'PROCESS_GUIDE_BOOK'. It includes folders like 'Figures', 'Rosmose', and 'frontend_MER_files', as well as various HTML and QMD files. The file 'equipment_cost.qmd' is selected.
- Code Editor:** The main area shows a Python code cell for 'equipment_cost.qmd'. The code is:

```
1 {python}
2 from equipment_costs import
3 cost_compressor_axial
4
5 Cost_BM, Cost_TM, Cost_GR =
6 cost_compressor_axial(1000)
7
8 print(Cost_BM, Cost_TM, Cost_GR)
```

A red circle highlights the variable 'Cost_TM' in the assignment on line 5.
- Output Area:** The right side shows the execution of the code cell. It displays a 'TypeError: can only concatenate str (not "int") to s' error. The error message is partially obscured by a yellow highlight.
- Terminal:** The bottom panel shows the command prompt output. It indicates that 'equipment_costs' was installed from a local registry. The command used was: `python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi/ registry/pypi equipment_costs`. The output shows the package being downloaded and installed successfully.

Change the input. Error, Why?

Equipment Cost Calculation - Pump

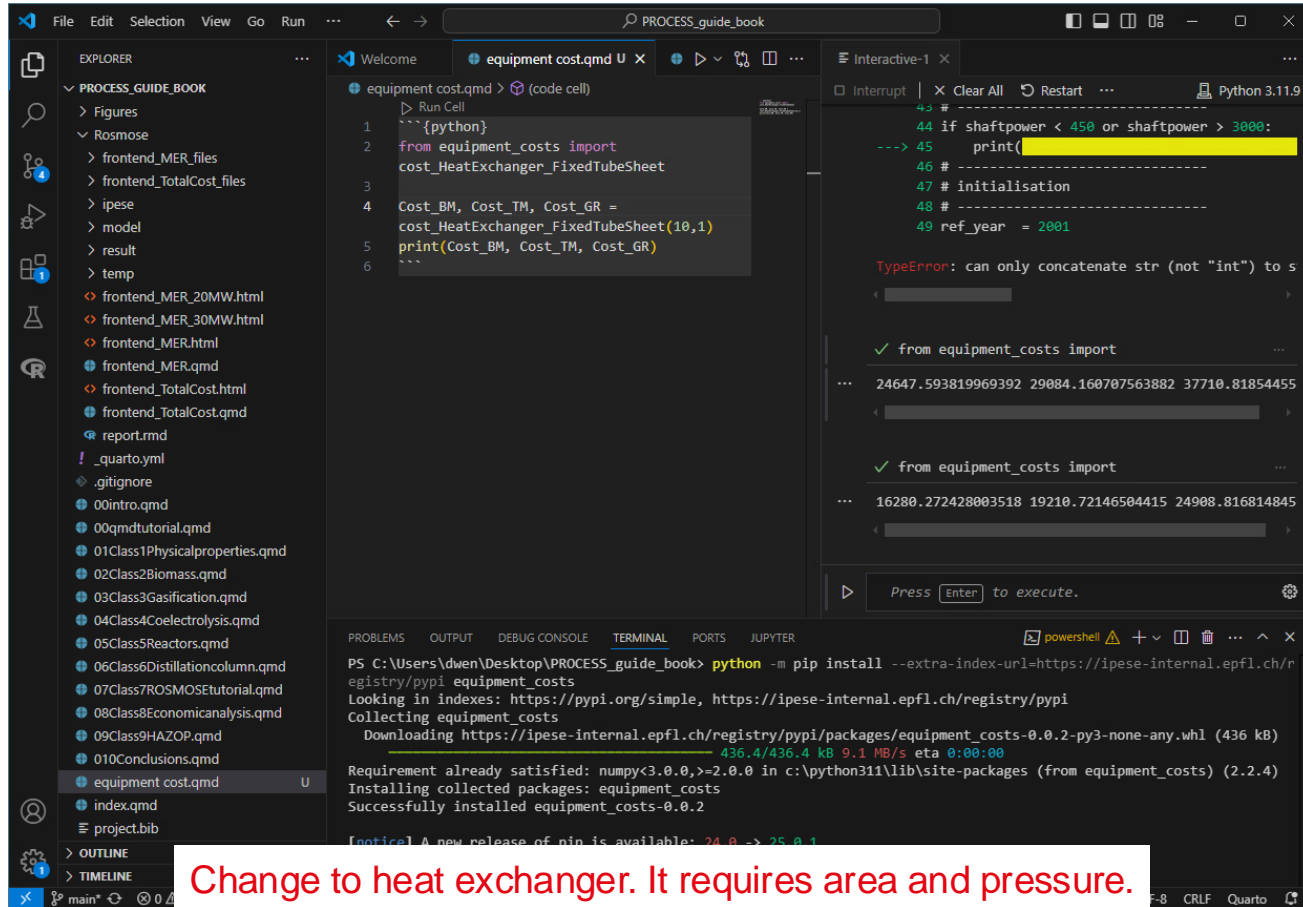
The screenshot displays a JupyterLab environment with the following components:

- EXPLORER:** A file tree on the left showing the project structure, including folders like `Figures`, `Rosmose`, and `frontend_MER_files`, and files like `frontend_MER_20MW.html`, `frontend_MER_30MW.html`, `frontend_MER.html`, `frontend_MER.qmd`, `frontend_TotalCost.html`, `frontend_TotalCost.qmd`, `report.rmd`, `_quarto.yml`, `.gitignore`, `00intro.qmd`, `00qmdtutorial.qmd`, `01Class1Physicalproperties.qmd`, `02Class2Biomass.qmd`, `03Class3Gasification.qmd`, `04Class4Coelectrolysis.qmd`, `05Class5Reactors.qmd`, `06Class6Distillationcolumn.qmd`, `07Class7ROSMOSETutorial.qmd`, `08Class8Economicanalysis.qmd`, `09Class9HAZOP.qmd`, `010Conclusions.qmd`, `equipment.cost.qmd` (selected), `index.qmd`, and `project.bib`.
- Code Editor:** The main area shows a Python script in `equipment.cost.qmd` (code cell) with the following code:

```
1 {python}
2 from equipment_costs import
  cost_pump_centrifugal
3
4 Cost_BM, Cost_TM, Cost_GR =
  cost_pump_centrifugal(10,10)
5 print(Cost_BM, Cost_TM, Cost_GR)
6
```
- Interactive-1:** The output area shows the execution of the code, displaying a `TypeError: can only concatenate str (not "int") to s` error. Below the error, the output of the `print` statement is shown: `24647.593819969392 29084.160707563882 37710.81854455`.
- TERMINAL:** The bottom panel shows the terminal output of the `python -m pip install` command, indicating that the `equipment_costs` package is being installed from the EPFL internal registry.

Change to pump. It requires not only power but also pressure.

Equipment Cost Calculation – Heat Exchanger



The screenshot displays a Jupyter Notebook environment with the following components:

- EXPLORER:** A file tree on the left showing the project structure, including folders like 'PROCESS_GUIDE_BOOK' and 'Rosmose', and various QMD files.
- Code Editor:** The main area showing a Python script in 'equipment cost.qmd'. The script defines a function 'cost_HeatExchanger_FixedTubeSheet' and calls it with arguments (10, 1).

```
1 {python}
2 from equipment_costs import
  cost_HeatExchanger_FixedTubeSheet
3
4 Cost_BM, Cost_TM, Cost_GR =
  cost_HeatExchanger_FixedTubeSheet(10,1)
5 print(Cost_BM, Cost_TM, Cost_GR)
6
```
- Interactive-1:** The output area showing the execution of the code cell. It displays a list of costs: 24647.593819969392, 29084.160707563882, 37710.81854455, and 16280.272428003518. A red error message is visible: 'TypeError: can only concatenate str (not "int") to s'.
- TERMINAL:** The bottom panel showing the command prompt output. It displays the command 'python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi equipment_costs' and the resulting installation of 'equipment_costs-0.0.2-py3-none-any.whl' (436 kB).

Change to heat exchanger. It requires area and pressure.

Equipment Cost Calculation - Overview

The screenshot displays a JupyterLab environment with the following components:

- EXPLORER:** A file browser on the left showing a project structure for 'PROCESS_GUIDE_BOOK'. It includes folders like 'Figures', 'Rosmose', and 'model', and files such as 'frontend_MER_files', 'frontend_TotalCost_files', 'ipese', 'result', 'temp', 'frontend_MER_20MW.html', 'frontend_MER_30MW.html', 'frontend_MER.html', 'frontend_MER.qmd', 'frontend_TotalCost.html', 'frontend_TotalCost.qmd', 'report.rmd', '_quarto.yml', '.gitignore', '00intro.qmd', '00qmdtutorial.qmd', '01Class1Physicalproperties.qmd', '02Class2Biomass.qmd', '03Class3Gasification.qmd', '04Class4Coelectrolysis.qmd', '05Class5Reactors.qmd', '06Class6Distillationcolumn.qmd', '07Class7ROSMOSETutorial.qmd', '08Class8Economicanalysis.qmd', '09Class9HAZOP.qmd', '010Conclusions.qmd', 'equipment.cost.qmd' (selected), 'index.qmd', and 'project.bib'.
- Code Cell:** The main editor shows a Python code cell named 'equipment.cost.qmd'. The code is as follows:

```
1 > Run Cell
2 {python}
3 from equipment_costs import
4 cost_VerticalVessels
5
6 Cost_BM, Cost_TM, Cost_GR =
7 cost_VerticalVessels(1,3,10)
8 print(Cost_BM, Cost_TM, Cost_GR)
9
```
- Interactive-1:** A console window on the right showing the execution of the code. It displays a `TypeError: can only concatenate str (not "int") to s` error, followed by several lines of output showing cost calculations for different equipment types, including 'from equipment_costs import' and numerical results like '24647.593819969392 29084.160707563882 37710.81854455'.
- TERMINAL:** A terminal window at the bottom showing the command `python -m pip install --extra-index-url=https://ipese-internal.epfl.ch/registry/pypi equipment_costs` and its output. The output indicates that the package 'equipment_costs' is being collected and downloaded from the specified URL. It also shows that the requirement is already satisfied for 'numpy<3.0.0,>=2.0.0 in c:\python311\lib\site-packages (from equipment_costs) (2.2.4)' and that the package was successfully installed.

Change to vertical vessel. It requires diameter, height, and pressure.

What is the bare module cost of a centrifugal compressor with 500 kW?

What is the bare module cost of a reciprocating pump with 100 kW and 1 bar?

What is the bare module cost of a double pipe heat exchanger with 100 m² and 10 bar?

What is the bare module cost of a horizontal vessel with 1 m in diameter, 3 m in length, and 10 bar?