

Energy and Flexibility Modelling Hands-on exercise 11: Installing FlexTool

Pease use the following citation for this exercise:

Pooya Hoseinpoori, Alex Kell, & Adam Hawkes. (2021, March). Hands-on 11: Energy and Flexibility Modelling (Version 1.3) <u>https://doi.org/10.5281/zenodo.4618320</u>

Please download the IRENA FlexTool Package from this link

Learning outcomes

By the end of this exercise you will be able to:

- 1) Install and use FlexTool on your computer
- 2) Diagnose possible installation errors
- 3) Become familiar with the tool interface and different files
- 4) Run a model on your computer and get the result file

About FlexTool

IRENA FlexTool is a software package developed by IRENA and VTT Technical Research Centre of Finland published under GNU Lesser General Public License. Users are free to modify and redistribute the software under LGPL. New versions will be published on <u>irena.org</u>. The main aim of the tool is to make a quick but yet thorough assessment of potential flexibility gaps and identify the cost-effective mix of options to fill such gaps.

Note: To be able to use FlexTool, users must have Excel on their machines.



Installing FlexTool

There are a few easy steps for Installing FlexTool :

Downloading FlexTool and extracting to disk

- a) Download FlexTool from the following link to IRENA's website <u>https://www.irena.org/energytransition/Energy-System-Models-and-Data/IRENA-FlexTool</u>
- b) FlexTool can be run from anywhere on the computer. Therefore you can save the file in any place on your computer. Here we install FlexTool on "c:\FlexTool". Create a folder named "FlexTool" in your C drive and extract the downloaded zip file to it. We will call this the "root folder".

File Home Share	View			^.
in to Quick Come Ports	Cut Copy path Paste shortcut Delete to Organise	Rename New Item		Select none
🗧 🔿 👻 🕇 📙 > Thi	s PC > Local Disk (C:) > FlexTool > FlexT	ool-v2.0 🗸	ල් ා Search Flex	Tool-v2.0
Quick access Desktop Bownloads Documents Pictures Pictures FlexTool-v2.0 InputData Results OneDrive	Name InputData gitattributes G	Date modified 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56	Type Siz File folder GITATTRIBUTES File GITIGNORE File MD File Application VBScript Script File Text Document MOD File Microsoft Excel M Application exten	1 KB 1 KB 8 K8 2,221 KB 1 KB 8 K8 35 KB 161 K8 759 KB
CD Drive (E:) virtio-w	glpsol.exe glpsol.exe mportRes.vbs paramNotWritten.dat	07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56	Application VBScript Script File DAT File	544 KB 1 KB 1 KB
Network	README.md README.txt Result file explanations.xlsx	07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56	MD File Text Document Microsoft Excel W	1 KB 1 KB 17 KB
	SheetsForm.frm SheetsForm.frx showForm.bas	07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56	FRM File FRX File BAS File	16 KB 4 KB 1 KB
	start_optimization.bat ThisWorkbook.cls variables.bas	07/02/2021 20:56 07/02/2021 20:56 07/02/2021 20:56	Windows Batch File CLS File BAS File	2 KB 1 KB 1 KB

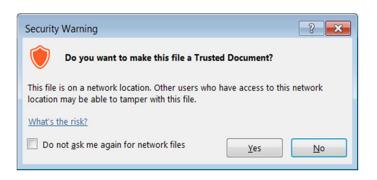
Figure 1: FlexTool root folder. The main interface file **flexTool.xlsm** is highlighted. The input file can be found in the **InputData** folder

c) The extracted folder contains an **InputData** folder where you can find input excel workbooks, the executables files and the main interface of the tool, which is an excel file named flexTool.xlsm (highlighted in Figure 1).



Enabling macros in the main worksheet

- a) From the root folder, open "flextTool.xlsm" excel file.
- b) You may be asked if you trust the document. Click "yes"



c) After opening the file you should enable content of the workbook

File	Home	Insert	Page Layout	Formulas	Data	Review	View	Help	Format	į.	Ç
	🔏 Cut		~	A	Ă	= = =	87 -	ab Wrap	Text	1	G
Paste *	🐝 Format P Slipboard	ainter	B I U -		A •	= = =	Align		je & Center	*	5
-			me active conten	0.699		ck for more o		parenter an	Content		
Picture	21 *	×	√ fx								
A	В		с					D	1		

- d) Enable macros:
 - 1. From the excel menu go to "File" -> "Options".
 - 2. Then from the left pane select "Trust Center"
 - 3. Click on "Trust Center Settings"
 - 4. A new window will open. From the left pane select "Macro Settings"
 - 5. Enable "Trust access to the VBA project object model"
 - 6. Click "OK" to save settings and close.

Note: These steps are needed only for the first time you run the tool.



cel Options		?	1
Seneral Formulas	💓 Help keep your documents safe and your computer secure and healthy.		
roofing	Security & more		
ave	Visit Office.com to learn more about protecting your privacy and security.		
anguage	Microsoft Trustworthy Computing		
ase of Access	Microsoft Excel Trust Center		
dvanced	The Trust Center contains security and privacy settings. These settings help keep your	Irust Center Settin	~~
ustomize Ribbon	computer secure. We recommend that you do not change these settings.	Irust Center Setun	gs
uick Access Toolbar			
dd-ins			
rust Center			

rust Center			?	×
Trusted Publishers Trusted Locations Trusted Documents Trusted Add-in Catalogs Add-ins ActiveX Settings	Macro Settings Disable all macros without notification Disable all macros with notification Disable all macros except digitally signed macros Enable all macros (not recommended; potentially dangerous code can run) Developer Macro Settings			
Macro Settings Protected View Message Bar External Content File Block Settings Privacy Options	✓ Trust access to the <u>V</u> BA project object model			
		OK	Car	ncel



Error:	Cause/Possible solution
Result file created but empty	Solver memory issue, CLP can handle
	larger models than GLPSOL
Programmatic access to visual basic project	Check macro settings. "Trust access to the
is not trusted	VBA project object model" have to be
	selected
flexmodel.mod:240: ts_inflow[NODE,0] out	You may have wrong time series, try to
of domain (or similar)	update the time series
Anti-virus program blocks some of the	Make an exception in the anti-virus
used executables: clp.exe, glpsol.exe,	program for the executable
wtee.exe	

Troubleshooting:

If optimization fails check errors from Results/Input data file name/Scenario name/output_[D/I]_y.txt.

(x = scenario number, y = phase number in optimisation, D/I = dispatch or investment mode)

The table above summarizes the possible errors you may encounter in the installation process and possible causes and solutions.



The main files

The tool includes three main MS Excel files:

- The main flexTool.xlsm file
- Input data files
- Result files
- 1) The **flexTool.xlsm** file acts as the interface to the tool. It is used to select the model and scenario used in the simulation, start running the model and define the sensitivity cases in "Sensitivity definitions" sheet.

Run Scenarios Import results Import summary only Write time series	Options for the modelling process: Useve results file open after importing res import results after optimisation Create plots in the results file Use parallel calculation (no. of threads in Run in the background			Sensitivity definitions Settings and filters FIEXTOOSI
and Run Scenarios	1.400 - 1.0			
Active input files:	Inactive input files:	Active scenarios:	Inactive scenarios:	Instructions
template.xlsm	<>>	Base	<>>	General
	<>>	Invest	<->	- This file contains macros. Macros must be enabled for this sheet and for Excel in general. See 'Getting Started' for more info.
	<-> demoModel-1.xlsm		<->	- Edit only blue and light blue cells
	42		demo1_invest_transCap	
	<-> demoModel-2-2017.xlsm		<-> demo1_invest_genCap	Run scenarios:
	demoModel-2-2030.xlsm		demo1_invest_storages	- Tool will run all the active scenarios in the right selection for all the active input files in the left selection
	↔		<-> demo1_invest_all	- Swap scenarios or input files on or off using the green arrows
	<-> template-EVs.xlsm		<->	- Write new input file or scenario names to either column
	<->		<-> demo2_storages	
			demo2_PV	Sensitivity definitions: - Tool will create parameters for the scenarios in the right selection area using the changes defined in the 'Sensitivity definitions' sheet
	(c)		<-> demoz_windGas	
	(c)			 The scenario name has to be exactly the same in both sheets (case sensitive) If there are no data changes defined in the 'sensitivity definitions' for a particular scenario, then the scenario is run without changes (i.e. a base scenario)
	6		template storageMW	 In there are to data changes defined in the sensitivity definitions for a particular scenario, then the scenario is run without changes (i.e. a dase scenario) Data structure is the same as in the input files. All other data can be changed in the 'sensitivities definitions' except for time series.
	62		template_storage/www stemplate_storage/ree	 - Data structure is the same as in the input files. All other data can be changed in the sensitivities derinitions' except for time series. - In the 'sensitivity definitions' sheet, the input data sheet names must be repeated at each row in the light grey column (B).
	4		<-> template_storagerree	 In the sensitivity deminions sheet, the input data sheet names not be repeated at each low in the ngit grey column (6). New rows can be added as needed.
			template_changeDemand <> template_changeTransfer	
			<>> template_change nansien	Japacity Import results:
			() ()	import results' will import active ('to be run') scenarios from active input files
	6		6	 Import results with import active (to be full scenarios from active input nies) Results can be also imported automatically using the checkbox 'Import results after optimisation'
	63		62	- results and the use inserted when internet using the encerted in insert results after optimisation
	(3)		63	- Only cases with same grids and nodes can be correctly collected to the same result excel file
	() ()		() ()	 Only cases with same groups and needs to be concerned to the same task in the same task in the same file sontaining different energy systems can be optimised at the same time, but it is better not to import them to the same file
			6	input they containing an inclusing systems can be optimised on the same time, but it is better not to import them to the same me

2) **Input file:** In FlexTool the Input data file define the model version. The flexTool.xlsm file is the same for all countries or regions, but input data is unique and case-specific. Therefore every case, region or model year needs its own input data file (e.g., Thailand 2019, Thailand 2030).



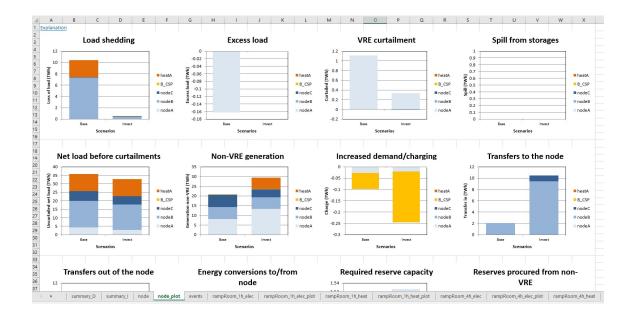
1	A	В	С	D	E	F	G	1	J	к	L	м	N	0	P	Q	1
1	grid	node	nodeGroup	nodeGroup2	demand (MWh)	import (WWh)	capacity margin (MW)	use ts_reserve	use dynamic reserve	print results	color in results	IREN	empty row A exT	ଇଆ			
2	elec	nodeA	mainland		7008000	350400	35	1	0	1							
3	elec	nodeB	mainland		2190000		10	1	0	1							
4	elec	nodeC	mainland		3504000		20	1	0	1							
5	elec	nodeD			438000		5	1	1	1							
6																	
7																	
8																	
9																	
10																	
11					-												
4	•	info m	aster node(Group gridN	ode unit_ty	/pe fuel	unitGrou	qu	units	node	eNode	ts_cf	ts_inflow	ts_energy	ts_im	por	+

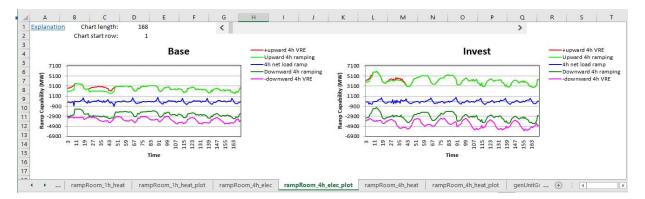
3) **Result output files:** The results file includes a diverse range of results for all the scenarios. The user can show only one scenario or to compare results from multiple scenarios.

Once you run the model, a result folder is generated in the root folder which contains the result output excel files.

1	А	В	С
1	Update sheets window	template	template
2		Base	Invest
3	Status	Optimal	Optimal
4	Optimal objective	1.06E+11	5203698667
5	Iterations	211	286
6	Solving time (s)	0.272	0.362
7			
8	Total cost obj. function (M CUR)	106431	5203.7
9	Total cost calculated (M CUR)	107108.2721	6247.177294
10	Operational cost of units (M CUR)	1357.965577	1348.286882
11	Investment cost of units (M CUR)	0	183.1187884
12	Investment cost for transfers (M CUR)	0	8.86285496
13	Penalty costs (M CUR)	105750.3066	4706.908769
14	Curtailment payments (M CUR)	55.37235204	16.66851774
15			
16	Time in use in years	0.022146119	0.022146119
17	Full time series in years	1	1
**	summary_D summary_l not	de node_plot	events rampRo







Running a model

As we said in FlexTool, the input data file will define the model version. A few models and templates are included in the package and you can read them from "InputData" folder in the root folder.

- "template.xlsm" is the template to create new models
- "template-XX.xlsm" are additional example templates with specific technologies
- Other input data files such as country-specific or versions for different years demo models.



To run a model:

- Open the interface worksheet ("flexTool.xlsm"). Make sure macros are enabled, as explained above.
- Navigate to "Sensitivity scenarios" sheet.
- Click on the first cell in "Active input files" column.
- A file picker opens. Select "template.xlsm" from **InputData** folder and click "Open".

Clipboard 5			Number 5		Insert Delete Forma Cells		Find &				
* E × ✓ . 8	C D	E F	G H	1.1	J		K L	м	N O	P	,
Run Scenarios	Options for the modelling process:	1.00		Sensitivity definitio	15						
Run Scenarios	Leave results file open after importing results	ults		Settings and filters	-						
Import results	Import results after optimisation				IRENA						
import results	Create plots in the results file				INLINA						
Import summary	Use parallel calculation (no. of threads in t	the cottings sheet)		💶 Open						×	4
only	Run in the background	ine second source()			is PC → Local Disk (C:) → FlexTool → FlexT	ool-v2.0 → InputData	~	ڻ ب Sear	ch InputData		
	With in the background			Organise • New fold	er.				80. •		
Write time series					Name	Date modified	Type	Size	Acc. 7		1
and Run Scenarios				🖈 Quick access	demoModel-1.xism	07/02/2021 20:56	Microsoft Excel M	4.402 KB			
active input files:	Inactive input files:	Active scenarios:	Inactive scenarios:	🔲 Desktop 🛛 🖈	demoModel-1-select weeks.xlsx	07/02/2021 20:56	Microsoft Excel W	2,625 KB			
emplate.xlsm	<>	Base	65	🕹 Downloads 🖈	demoModel-2-2017.xlsm	07/02/2021 20:56	Microsoft Excel M	4,119 KB			
	demoModel-1.xism	Invest	60 60	Documents 🖈	demoModel-2-2030.xism	07/02/2021 20:56	Microsoft Eccel M	4,119 KB			
			demo1_invest_transCap	Pictures 🖈	template.xlsm	07/02/2021 20:56	Microsoft Excel M	3,823 KB			
	<-> demoModel-2-2017.xlsm		demo1_invest_genCap	flextool	template-EVs.xlsm	07/02/2021 20:56	Microsoft Excel M	3,193 KB			
	<-> demoModel-2-2030.xlsm		<-> demo1_invest_storages	FlexTool-v2.0							
	template-EVs.xlsm		demo1_invest_all	InputData							
	<>> template-cv3.xisiii		<-> demo2 storages	Results							
	<>>		<-> demo2_PV	Microsoft Excel							
	•		demo2_windGas	OneDrive							
			(c) (c)	This PC							na
	₩ ₩		<>> template storageMW								
	↔		template_storageFree	CD Drive (E:) virtic *	-						
	•		template_changeDeman		ame: template.xlsm			MS Excel	(*2lx.*)	~	
	(c) (c)		<-> template_changeTransfe <->	n			Too	ls ▼ <u>Ω</u> per	1 Ci	ancel	
	↔ ↔		6	- 'Import results' wil	(import active ('to be run') scenarios fro	om active input files					1
	•		60		imported automatically using the chec		optimisation'				
	↔		(c)								
			<->		ne grids and nodes can be correctly coll different energy systems can be optin						
	(c) (c)		<>>	- Input files contains							

- In "Active Scenarios" column, activate the "Base" scenario.
- You can toggle scenarios active or inactive by clicking on the green arrow ("<->").
- Only scenarios in the "Active Scenarios" column will be run by the model.

Active scenarios:		Inactive scenarios:
Base	<->	
	<->	Invest
	<->	
	<->	demo1_invest_transCap
	<->	demo1_invest_genCap
	<->	demo1_invest_storages
	<->	demo1_invest_all
	<->	
	<->	demo2_storages
	<->	demo2_PV
	<->	demo2_windGas
	<->	
	<->	



• Click on "Write time series and Run Scenarios" to start running the model.

Note: Input file must be closed before running the model. If the input file is still open FlexTool will warn you to close the file.

- A prompt window will open while the model is running to display the status of the execution.
- In "Options for the modelling process" you can set various processing options.

Options for the modelling process:
Leave results file open after importing results
Import results after optimisation
Create plots in the results file
Use parallel calculation (no. of threads in the settings sheet)
Run in the background

C:\Windows\system32\cmd.exe		2 <u></u>	×
Total number of scenarios:	1		~
Scenarios started so far:	1		
Scenarios not yet started:	0		
Scenarios currently ongoing:	1		
Scenarios failed:	0		
Scenarios already finished:	0		
			\sim

If the option is enabled, after successful execution of the model results file is automatically opened. In any case, results are automatically saved in the "Results" folder in the root directory.



In the results file go to the "summary_D" sheet which contains the most important results. You can use the quick selection window to find "summary_D" sheet to explore the results. The attributed input data files and scenarios are shown on the top two rows.

File Home Insert Page Layout Formula	is Data Revier	w Vie	w Help 🖓 Tell men	what you want to do								Sheets	>
Calibri V 11 V	A A = =	187.	ab Wrap Text	General 🗸		Normal	Bad			× 🗊	Σ Aut	FLEXIBILITY	
aste S Compt Puiston B I U + U + 🖄		-	Merge & Center +	\$ - % , 60 .00	Conditional Format as	Good	Neutral		Insert Del		😈 Fill 🕯	summary_D	
😴 💞 Format Painter	· A · = = ·		Merge & Center *	\$ * % * 00 →0	Formatting * Table *	0000					📌 Cle	node node plot	1
Clipboard 🖏 Font	r <u>s</u>	AI	ignment 🕫	Number 🕞		Styles			Cells			events	
1 * : × ✓ fx												rampRoom_1h_elec rampRoom_1h_elec_plot	
1 · · · · / // //												rampRoom_1h_heat rampRoom_1h_heat_plot	
A	B	С	D				E	F	G	н	1	rampRoom_4h_elec	
Update sheets window	template											rampRoom_4h_elec_plot	_
	Base											OPERATIONS	
Status	Optimal		If the status is not optimal, then the results are not correct									genUnitGroup_elec genUnitGroup_elec_plot	
Optimal objective	1.06E+11		Objective value as given by the solver									genUnitGroup_csp	
Iterations	211		Number of iterations the solver performed before finding the optimal solution									genUnitGroup_csp_plot genUnitGroup_heat	
Solving time (s)	0.272		How long the solver tool	k to find the solution - do	oes not including data	processing before	e and after the	solver				genUnitGroup_heat_plot	
												units_elec units_elec_plot	
Total cost obj. function (M CUR)	106431		Minimized total system	cost as given by the solv	er (includes all penalty	costs and curtail	ment paymen	t for VRE	generation	not curtaile	≥d)	units csp	
Total cost calculated (M CUR)	107108.2721		Total cost calculated from	m variables and cost para	ameters							units_heat units_heat_plot	
Operational cost of units (M CUR)	1357.965577											transfers_elec	
Investment cost of units (M CUR)	0											transfers_elec_plot storageContent_elec	
Investment cost for transfers (M CUR)	0											storageContent_elec_plot	
Penalty costs (M CUR)	105750.3066											storageContent_csp storageContent_csp_plot	
Curtailment payments (M CUR)	55.37235204											storageContent_heat	
												onlineUnit_elec onlineUnit_elec_plot	
Time in use in years	0.022146119		The amount of time selected by the in_use or in_use_invest in the ts_time sheet of the input									inertiaUnit_elec reserveUnit_elec	
Full time series in years	1		The selected plus non-selected time defined in the ts_time sheet									grid_t_elec	
												grid_t_csp grid_t_heat	
Emissions												transfers_t	
CO2 (Mt)	5.38523		System-wide annualized	CO2 emissions								genUnit_elec genUnit_elec_plot	
												COSTS	-
General results	elec											costs	-
VRE share (% of annual demand)	26.59		Energy share of VRE									costs plot	
Loss of load (% of annual demand)	21.06		Share of unserved energy									costs_unitGroup costs_unitGroup_plot	
-> ramp up constrained (% of annual demand)	0		Unserved energy caused by upward ramp limitations									costs_t	
Excess load (% of annual demand)	oad (% of annual demand) 0.4634 Additional demand caused by minimum generation constraints								costs_t_plot	_			
Insufficient reserves (% of reserve demand)	0		Share of unserved reserved	ve								NODES	
Insufficient inertia (% of inertia demand)	0	0 Share of unserved inertia (out of total required MWs)										rampRoom 1h elec nodeA	
Curtailment (% of VRE gen.)	11.9		Share of curtailed VRE or	ut of total available VRE								rampRoom_1h_elec_nodeA_plot rampRoom_1h_elec_nodeB	
-> ramp down constrained (% of VRE gen.)	0	0 VRE curtailed to decrease downward ramp so that rest of the system manages to ramp up				р					rampRoom_1h_elec_node8_plot	8	
Peak load (MW)	5398.49		Highest demand in the modelled time series									rampRoom_1h_elec_nodeC rampRoom_1h_elec_nodeC_plot	8
Peak net load (MW)	4611.38		Highest demand minus \	/RE generation and impo	ort/export time series							rampRoom_1h_heat_heatA rampRoom_1h_heat_heatA_plot	ŝ.
												rampRoom_4h_elec_nodeA	
Flexibility issues	elec											rampRoom_4h_elec_nodeA_plot rampRoom_4h_elec_nodeB	8
Loss of load (max MW)	1539.69		Highest unserved demand in the results									rampRoom_4h_elec_nodeB_plot	2
Excess load (max MW)	-471.042		Highest forced demand increase to avoid model infeasibility									rampRoom_4h_elec_nodeC rampRoom_4h_elec_nodeC_plot	
Reserve inadequacy (max MW)	0		Highest deficit of upwar	d reserve								rampRoom_4h_heat_heatA	
Insufficient inertia (TWs/a)	0		Highest deficit in the ine	ertia								rampRoom_4h_heat_heatA_plot node t elec nodeA	£.

Activity: Try to run different combination of input files and scenarios that are included in the package and go through input files and results files to familiarize yourself with the Tool and content of each file.

In the following sessions you will learn to make your own input files and scenarios.