# HOW TO GUIDE

# Load changes energyPRO



### Preface

energyPRO is a Windows-based modeling software package for combined techno-economic analysis and optimisation of complex energy projects with a combined supply of electricity and thermal energy from multiple different energy producing units.

The unique programming in energyPRO optimises the operations of the plant including energy storage (heat, fuel, cold and electrical storages) against technical and financial parameters to provide a detailed specification for the provision of the defined energy demands, including heating, cooling and electricity use.

energyPRO also provides the user with a detailed financial plan in a standard format accepted by international banks and funding institutions. The software enables the user to calculate and produce a report for the emissions by the proposed project.

energyPRO is very user-friendly and is the most advanced and flexible software package for making a combined technical and economic analysis of multi-dimensional energy projects.

For further information concerning the applications of energyPRO please visit <u>www.emd.dk</u>.

## **Terms of application**

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## **1. Introduction**

The load change allows you to model ramping times of energy conversion units in energyPRO. This can be done in 4 different ways: by including restriction on load change frequency, including ramping times between load lines, restricting the time between load changes or attaching a payment to load changes a unit undergoes.

This How To Guide contains four main parts:

Section 2.1 - Load change 1: Time restrictions for consecutive unit changes
 Section 2.2 - Load change 2: Time restrictions for ramping between load lines
 Section 2.3 - Load change 3: Restriction to limit hourly ramping
 Section 3 - Load change payments

## 2. How to setup the load change restrictions in energyPRO

The energyPRO project case called: "Load change restrictions on a wood chip fired CHP" can be accessed from the English Project examples in the start window of energyPRO, please see Figure 1. The project is used in this guide to illustrate the load change restrictions in energyPRO. Each created alternative is in accordance with the described load changes 1 – 3 plus load change payment.



Figure 1. The energyPRO project case, "Load change restrictions on a wood chip fired CHP", used in this HowToGuide, having an alternative for each load change

To include the unit change restrictions in energyPRO, the MILP solver needs to be used as calculation method. To choose the MILP solver, first the project identification needs to be opened as seen in Figure 2.

<u>File</u> nergyPRO setup	o <mark>ject setup</mark> <u>T</u> ools <u>W</u> indow	License Help
🔿 📮 📂 🖽 😡   [	Project identification	🗞 💽 🛹   MILP   🕨
🛨 🗖 Input data	External condtions	100% 🗘 🔎 IIIII 🗚 🕂 🗙 💾 🛅 💿 🦓 Site Overview
Project identifica     External conditio	Financing	
V Sites		

Figure 2. Choosing project identification

In the project identification, the calculation method tab needs to be selected. In the tab the checkbox next to "MILP" is checked as seen in Figure 3.

Main settings Calcul	ation method Advance	ed settings   Measuring units		
Type of Solver				 
Analytic				
MILP				
MILP Settings				
Max. solution time:	120 û seconds	Ignore warning when m	ax. runtime is exceeded	
	•			
Wanted precision:	1.0000 %			
Choice of Solver				
Open source CBC		Open source	HIGHS	

Figure 3. Selecting the MILP-Solver in project identification

# 2.1 Load change 1: Time restrictions for consecutive unit changes

A new constraint is introduced to limit how long a unit is not allowed to change its load again after changing its load, specified as a number of timesteps. These timesteps are defined as the calculation step, which can be changed in "project identification", as seen in Figure 4. In the project example it is set to one hour.

O Project identification

lain settings	Calculation method	Advanced settings	Measuring units
Delivery of Starting up Fuel produ Enable uni Enable pric	f both heat and process o of production units is ucing energy units in pro- ts to operate in fixed pe- pritizing of electricity de	heat slow and expensive oject rriods mands for the Germa	n CHP law
Show warning	when demand is not m	iet:	
<ul> <li>Heat</li> <li>Process He</li> <li>Cooling</li> <li>Electricity</li> </ul>	eat		
Length of calc	ulation step	1 Hour 🗸	Warning when time series changes asynchronous with calculation step
Length of opt	imisation period	5 Minutes A 6 Minutes	nended) 🔿 Year
✓ Transfer sto	orage content between	mc 10 Minutes 12 Minutes	
Check input d	ata	15 Minutes 20 Minutes 30 Minutes 1 Hour Y	<ul> <li>Only before calculation</li> </ul>

#### Figure 4. Setting the length of a calculation step in project identification

The unit is not restricted to being at a specific load line – it can still partially load anywhere between minimum and maximum.

To add such a constraint the minimum time between load changes has to be entered into the field next to "Change load no more frequently than" (see Figure 5) as a number of timesteps.

□ ×

СНР		
Name: CHP		
Fechnical Operational		
Operational Unit Setup		^
Partial load allowed	$\checkmark$	
Production to store allowed	<b>&gt;</b>	
Electricity market	New Day ahead ma	ırk
Selected priority in operation strategy	Calculated	
		~
] Operation dependent on other unit		
Non availability periods	Ar	operation period shall min. be 0 x 60 minutes non operation period shall min. be 0 x 60 minutes
	CI	ange load no more frequently than 3 x 60 minutes

#### Figure 5. Adding time restriction between load changes

If the unit changed load, exactly the specified number of timesteps must pass before the load can be changed again. A shut down of the unit is also considered as a change in load, and n number of timesteps must pass before the unit can start again.

Be aware that if the Change load setting is higher than an operation or a non-operation period then the load change overrules these settings.

# 2.2 Unit change 2: Time restrictions for ramping between load lines

A second option to include restrictions on the ramping of units is to include ramping up and ramping down times to each load line added to the unit. These can be defined by what the maximum change in load is in one timestep. Eg. between two timesteps, a CHP cannot increase heat production by more than 1 MW and cannot decrease heat production by more than 2 MW, modelling a ramp up and ramp down respectively. This can be done if the unit is opened per right click and the check box next to "Load change restrictions", as seen in Figure 6. To be able to include such restrictions, at least two load lines need to be inserted. Furthermore, the checkbox next to "Time from one load to the next" needs to be checked.

Name:	CHP						
Technical Op	perational						
Production un	it type CHP	~					
Fuel input(s)	WoodCl	nips 🗸					
Load change	e restrictions						
<ul> <li>Load change</li> <li>Time from</li> </ul>	e restrictions one load line to t	he next	<ul> <li>Maximum load cl</li> </ul>	nange per tim	iestep		
<ul> <li>Load change</li> <li>Time from</li> <li>Power curves</li> </ul>	e restrictions one load line to t	he next	<ul> <li>Maximum load cl</li> </ul>	nange per tim	iestep		
<ul> <li>Load change</li> <li>Time from</li> <li>Power curves</li> </ul>	e restrictions one load line to t	he next nge restrictions	) Maximum load c	nange per tim	nestep wer Cur	ves Output	
<ul> <li>Load change</li> <li>Time from</li> <li>Power curves</li> <li>Operation</li> </ul>	e restrictions one load line to t Load char Ramp up to	he next nge restrictions Ramp down fron	<ul> <li>Maximum load cl</li> <li>Power Curves Input</li> <li>WoodChips input</li> </ul>	nange per tim Po Heat outpu	nestep wer Cur	ves Output Electricity ou	ıtput
<ul> <li>Load change</li> <li>Time from</li> <li>Power curves</li> <li>Operation</li> <li>Performance</li> </ul>	e restrictions one load line to t Load char Ramp up to minutes	he next nge restrictions Ramp down fron minutes	O Maximum load cl Power Curves Input WoodChips input MW	Po Heat output MW	wer Cur ut	ves Output Electricity ou MW	ıtput V
<ul> <li>Load change</li> <li>Time from</li> <li>Power curves</li> <li>Operation</li> <li>Performance</li> <li>Max.</li> </ul>	e restrictions one load line to t Load char Ramp up to minutes 120	he next nge restrictions Ramp down from minutes 120	O Maximum load cl Power Curves Input WoodChips input MW 4 20	Po Heat outpu 4	wer Cur ut 9.6	ves Output Electricity ou MW	itput

Figure 6. Adding load restrictions to load lines

The ramping times can be included for every load line above the minimum load. The times should be entered in minutes. They specify the time it takes to ramp from up from the load line below ("Ramp up to") and the time it takes to ramp down to the load line below ("Ramp down from").

This can be combined with the feature described in Chapter 2.1 to include a restriction for the amount of unit changes in a time frame.

### 2.3 Unit change 3: Restriction to limit ramping per timestep

To include a restriction on how much a unit can ramp in a specified time frame (see Figure 4), first the checkbox next to "Load change restrictions" is activated. Then the checkbox next to "Maximum load change per timestep" is selected as seen in Figure 7.

									-	)
Name:	CHP									
Technical Op	erationa	Ι								
Production uni	t type	СНР	~							
Fuel input(s)	[	WoodChips	~							
I load change	erestricti	0.05								
	restricti	ons								
O Time from	one load	l line to the next		<li>Max</li>	cim	num load cł	hange p	er timestep		
- Downer cupier										
Power curves				1				1		
Fower curves		Power Curves Ir	nput	Power C	ùn	ves Output				
Operation	Wood	Power Curves Ir Chips input	nput	Power C Heat output	ùn	ves Output Electricity (	output			
Operation Performance	Wood	Power Curves Ir Chips input	nput 🗸 🗸	Power C Heat output MW	ùn V	ves Output Electricity o MW	output			
Operation Performance Linear	WoodO	Power Curves Ir Chips input	nput V 20.4	Power C Heat output MW 9	un ~ 9.6	ves Output Electricity o MW	output v 8.4			
Operation Performance Linear	WoodO	Power Curves Ir Chips input	nput v 20.4	Power C Heat output MW 9	un ~ 9.6	ves Output Electricity o MW	output v 8.4			
Operation Performance Linear	Woodd	Power Curves Ir Chips input	nput 20.4	Power C Heat output MW 9	`un ♥ 9.6	ves Output Electricity o MW	output V 8.4			
Operation Performance Linear	Wood0 MW	Power Curves Ir Chips input	nput v 20.4	Power C Heat output MW 9	€ 0.6	ves Output Electricity o MW	output v 8.4			
Operation Performance Linear	Wood( MW	Power Curves Ir Chips input ine Enable f	nput 20.4 formulas in po	Power C Heat output MW 9 9 wer curve	€ 0.6	ves Output Electricity o MW	output v 8.4			

Figure 7. Activating load change restrictions for a maximal load change per hour

A new menu for load change restrictions will appear as seen in Figure 8.

<ul> <li>Load change restrictions</li> </ul>		
Energy type	Electricity output 🗸 🗸	
Maximum ramp up	WoodChips input Heat output	MW / 60 Minutes
Maximum ramp down	Electricity output	MW / 60 Minutes

Figure 8. Menu for maximal load change per timestep

Here the energy type that the load restrictions apply to can be selected in a dropdown menu. The dropdown menu will give options for all existing power curves in the unit.

For the selected energy type a maximum ramp as well as a maximum ramp down can be assigned. The maximum ramp up specifies how many MW of the selected energy type can be ramped up in a timestep. The maximum ramp down specifies the amount of MW that the unit can ramp this energy type down in a timestep.

# 3. Payment for load changes

Another possibility to restrict the load changes of a unit, is to attach a payment to load changes, meaning that a payment must be performed each time a unit changes its load. To create such a payment, a payment must be added to the project by right clicking operation expenditures and selecting Add Payment. This payment should be opened, as seen in Figure 9

		CHP	me: Load change CHP
			Jnit Selection
		ns	Payment concerns
		~	User defined
		g amounts in each timesten	Formula colocting amo
			Formula selecting amo
			Formula selecting anto
		IP)	LoadChange(CHP)
		IP)	LoadChange(CHP)
		(P)	LoadChange(CHP)
		(P)	LoadChange(CHP)
2	Fixed monthly price	IP) 0000 €/ change	Price per Unit
2	Fixed monthly price	IP) 0000 €/ change	Price per Unit
		ns 🗸	Payment concerns User defined

#### Figure 9. Setting up a payment on load changes

The payment is set up by double-clicking the red marked cell, opening up the menu shown in Figure 10.

O List of functions			- 🗆 ×
Formula			
LoadChange(CHP)			<b>f</b> r∗∕ OK
			Cancel
Euroction to select	Unit	Description	^
APeakImportedElectricity(MARKET:PERIOD)		Annual peak imported electricity	
Production Unit Level	[]	A window pour imported electricity	
HP(PRODUCTIONUNIT)	[MWh]	Heat production	
	[MWh]	Electricity production	
	[MWh]	Cooling production	
FP(PRODUCTIONUNIT:FUEL)	[MWh]	Fuel production	
FC(PRODUCTIONUNIT;FUEL)	[MWh]	Fuel consumption	
EC(PRODUCTIONUNIT;PERIOD)	[MWh]	Electricity consumption	
HC(PRODUCTIONUNIT)	[MWh]	Heat consumption	
Turnons(PRODUCTIONUNIT)	[turnons]	Number of turnons	
Turnoffs(PRODUCTIONUNIT)	[turnOffs]	Number of turnoffs	
LoadChange(PRODUCTIONUNIT)	[loadchanges]	Number of loadchanges	
HoursOfOperation(PRODUCTIONUNIT)	[hours]	Hours of operation	
FullLoadHours(PRODUCTIONUNIT)	[hours]	Number of full-load hours	
AccFullLoadHours(PRODUCTIONUNIT)	[hours]	Number of full-load hours per year	
AccAllYearsFullLoadHours(PRODUCTIONUNIT)	[hours]	Number of full-load hours in planning period	
HPCap(PRODUCTIONUNIT)	[MW]	Heat production capacity	
EPCap(PRODUCTIONUNIT)	[MW]	Electricity production capacity	
ECCap(PRODUCTIONUNIT)	[MW]	Electricity consumption capacity	
FCCap(PRODUCTIONUNIT;FUEL)	[MW]	Fuel consumption capacity	
FPCap(PRODUCTIONUNIT;FUEL)	[MW]	Fuel production capacity	
HCCap(PRODUCTIONUNIT)	[MW]	Heat consumption capacity	
CPCap(PRODUCTIONUNIT)	[MW]	Cooling production capacity	
Demand functions			
HD(DEMAND)	[MVVh]	Heat demand	
ED(DEMAND;PERIOD)	[MWh]	Electricity demand	~

#### Figure 10. Selecting the LoadChange function for payments

In the list shown, the LoadChange function can be selected by double-clicking. The name of the unit that this payment is applied to, needs to be entered into the brackets, to attach the payments to this unit.

# 4. Production, graphic reports of all load changes

To illustrate the load changes described in sections 2.1 - 2.3 the graphic production reports of the project examples different alternatives are used. Figure 11 shows the production of the project example without any load change restrictions. The figure illustrates the production and consumption of heat and electricity over the duration of a week.



Figure 11. Production, graphic report of a reference model without load change restrictions

Figure 12 shows the production graphic of the load change described in section 2.1 which restricts the time distance between consecutive load changes. This is set to three hours in the example. In comparing the loads in Figure 12 to Figure 11 the load looks more stable and less fluctuating.





Figure 13 shows the production graphic of a unit that is restricted in its load changes between two load lines. Therefore, a minimum load is added from which it takes two hours to ramp up to nominal load and

two hours to ramp down from nominal load to minimum load. The operation of the unit is observed to be less often in nominal load than in Figure 11. Furthermore, no loads smaller than the minimum load can be observed.



Figure 13. Production, graphic report of Load change 2

Figure 14 shows the production graphic of a unit that is ramp its electricity production not more than 3 MW per hour, using the restriction described in section. It can be observed that the changes in electric and thereby in heat as well do not exceed a certain maximum. No ramps from no load to nominal load in an hour like in Figure 11 are present.



Figure 14. Production, graphic report of Load change 3

Figure 15 shows the production graphic of a CHP unit, with a payment of 10 € attach to load changes. This leads to a comparatively low number of load changes.



Figure 15. Production, graphic report of a payment of 10  $\in$  on each load change, included in operation strategy