



the
abdus salam
international centre for theoretical physics

SMR.1524 - 2

**College on Evaluation of Energy Technologies
and Policies for Implementation of Agenda-21**

10 - 28 November 2003

Modelling Combined Heat & Power Technology

**Arvydas GALINIS
Lithuanian Energy Institute
Laboratory of Basic Energy Research
Breslaujos 3
Kaunas Lt-3035
LITHUANIA**

These are preliminary lecture notes, intended only for distribution to participants

Modeling of Combined Heat and Power Plants

Arvydas Galinis
(galinis@isag.lei.lt)

Lithuanian Energy Institute

Topics covered

Single fuel back pressure units,

Multiple fuel back pressure units,

Single fuel extraction units,

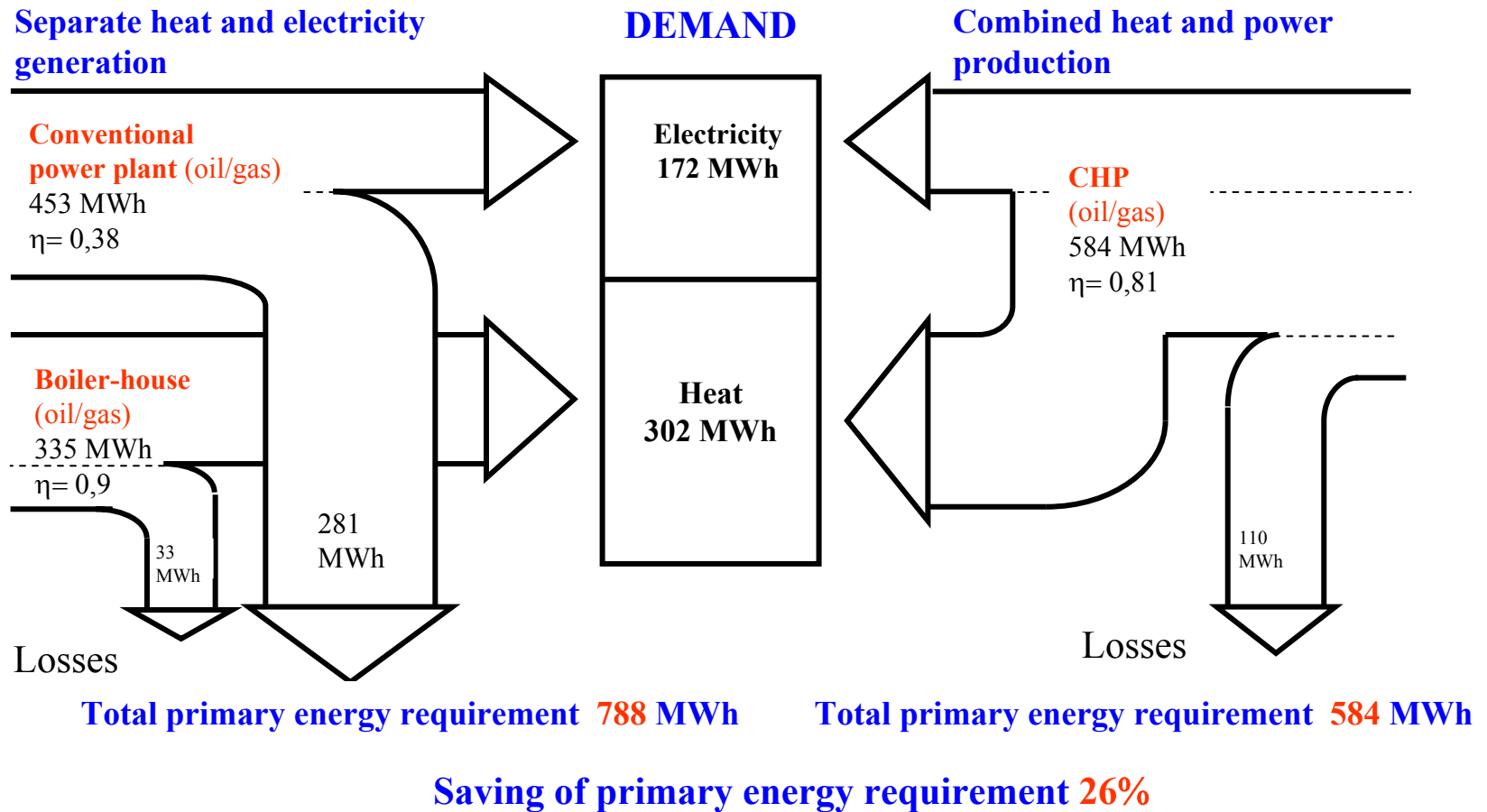
Multiple fuel extraction units,

Ability to cover heat and electricity demand,

CHP with heat accumulator,

Data example for case studies.

Combined and separate heat and electricity production



Types of combined heat and power plants

Back pressure CHP – relation between heat and electricity output is fixed,

Extraction CHP – heat and electricity output is not in a fixed relation.

Technical parameters of CHP's

Back pressure units

Nominal electrical capacity (P_n),

Nominal thermal capacity (Q_n),

Total fuel efficiency η_Σ

Relation between heat and electricity output

Electricity
(P)

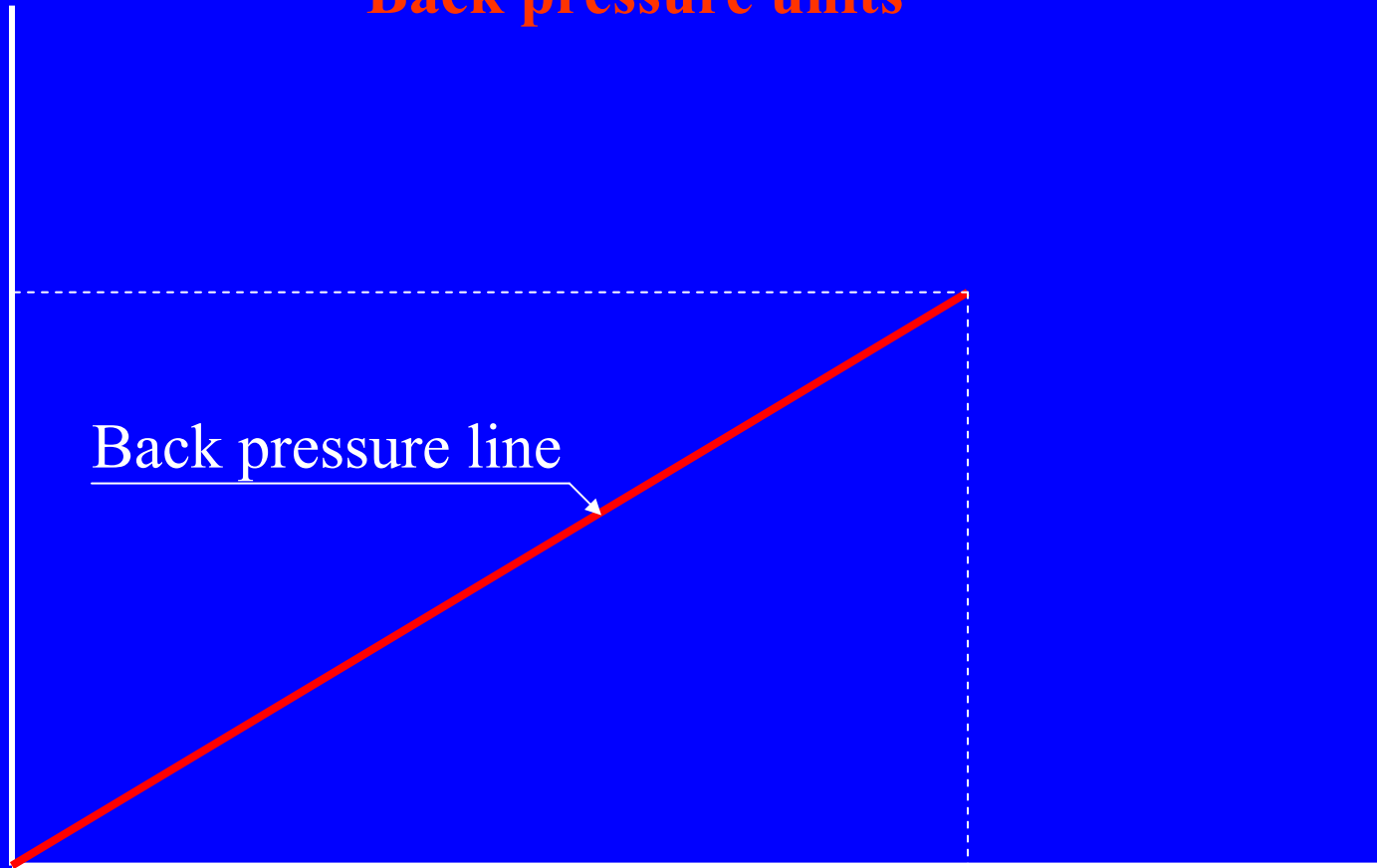
Back pressure units

P_n

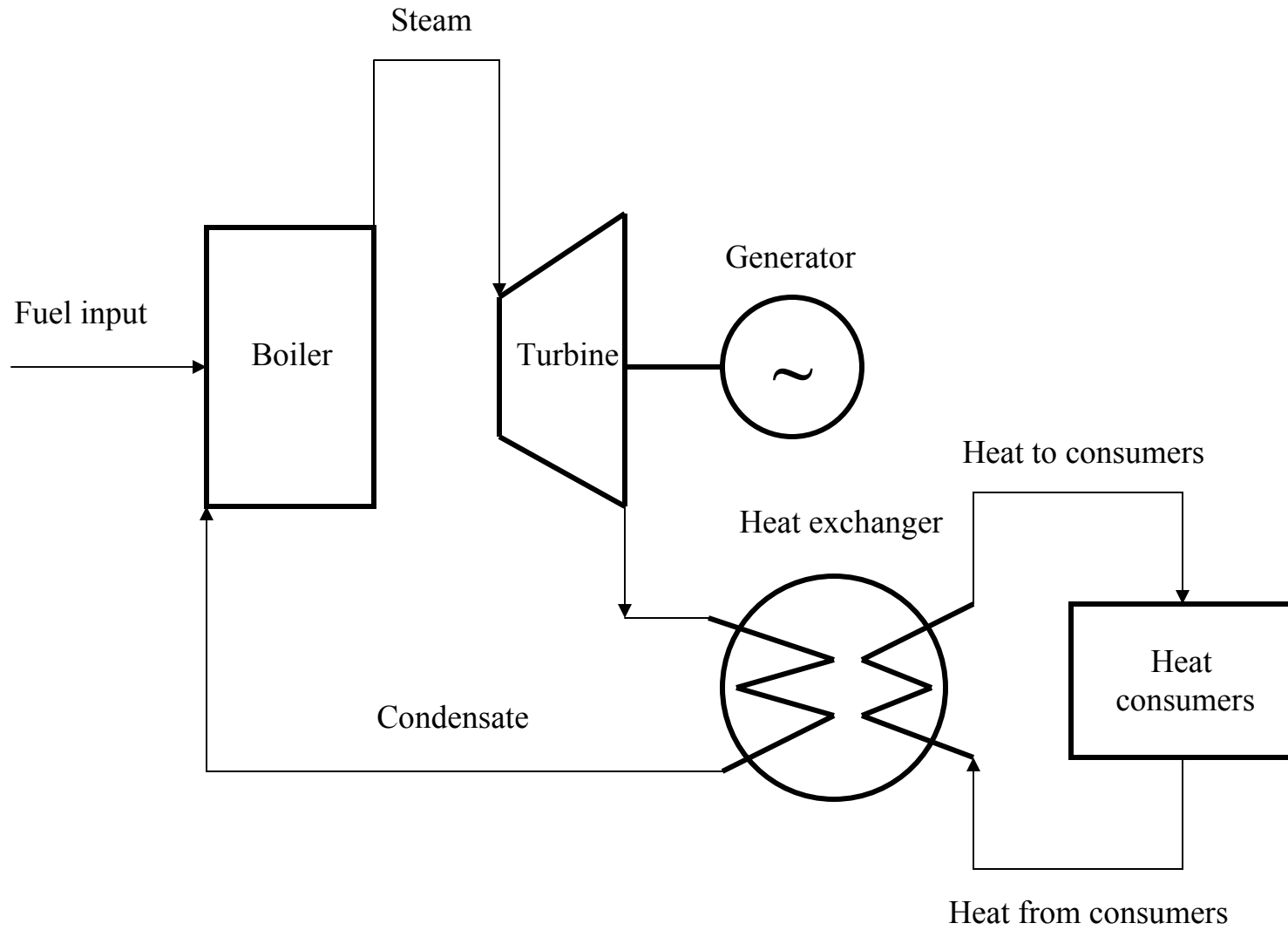
Back pressure line

Q_n

Heat (Q)

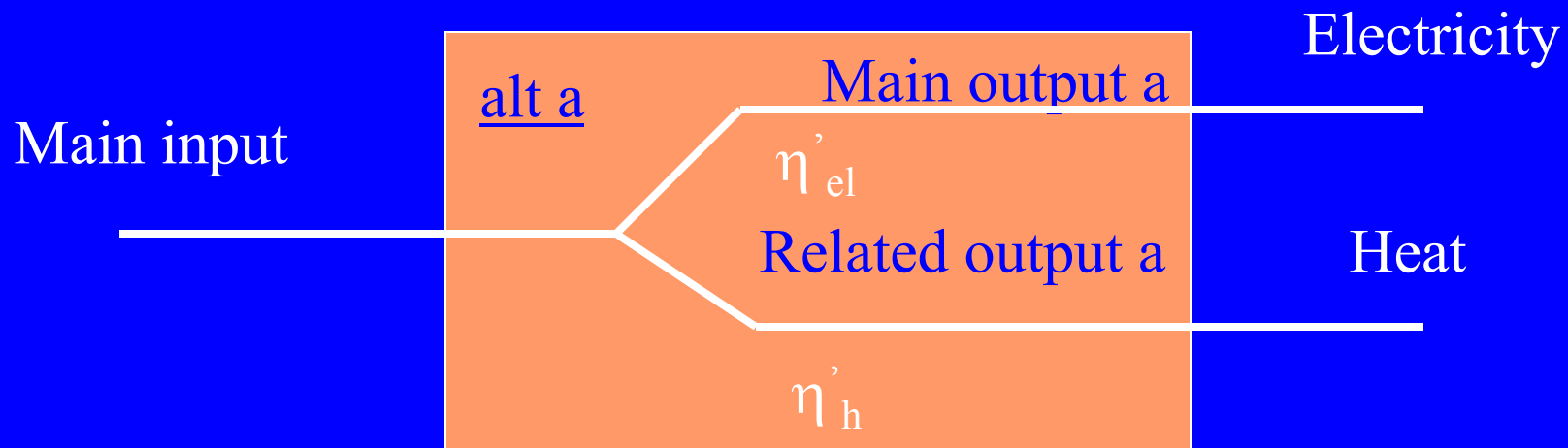


Back pressure units



Representation of CHP in MESSAGE

Back pressure unit



$$\eta'_{el} = \frac{P_n}{(P_n + Q_n)/\eta_\Sigma} ; \quad \eta'_h = \frac{Q_n}{(P_n + Q_n)/\eta_\Sigma} ; \quad \mathbf{P' = P_n} ;$$

Representation of CHP in MESSAGE

Back pressure unit

$$P_n = 23.3 \text{ MW}; \quad Q_n = 102.3 \text{ MW}; \quad \eta_\Sigma = 0.825;$$

$$P' = P_n = 23.3 \text{ MW};$$

$$\eta'_{el} = \frac{P_n}{(P_n + Q_n)/\eta_\Sigma} = \frac{23.3}{(23.3+102.3)/0.825} = 0.153;$$

$$\eta'_{h} = \frac{Q_n}{(P_n + Q_n)/\eta_\Sigma} = \frac{102.3}{(23.3+102.3)/0.825} = 0.672;$$

Cost data of CHP's

Back pressure units

Investment costs and fixed O&M costs are related to electrical capacity,

Variable O&M costs are related to electricity output.

Representation of CHP in MESSAGE

Back pressure units

The screenshot displays the MESSAGE software interface for configuring a CHP technology. The main window is titled "IAEA - MESSAGE lit_case2 adb" and shows the "Technologies" configuration screen. The "General" tab is active, showing various input and output parameters. A secondary window titled "IAEA - MESSAGE vil_chp2 fuels outp" is open, showing the "Secondary outputs" table. An orange arrow points from the "multiple entries" table to the "Secondary outputs" table. Two callout boxes highlight efficiency values: $\eta'_h = 0.672$ and $\eta'_{el} = 0.153$.

Technologies Configuration:

- input: all
- output: all
- relations: all
- name (re):
- has inv: all yes no
- operator: and or
- technologies: vil_chp2

Secondary outputs:

Fuel	ti	Unit	Tmssw	Data
Heat_Vilnius_area/output			c	0.672

single entries:

Name	Unit	Value
main input Gas/transported	kWyr	1.0
main output EI_after_KHPSP/After_f	kWyr	0.153

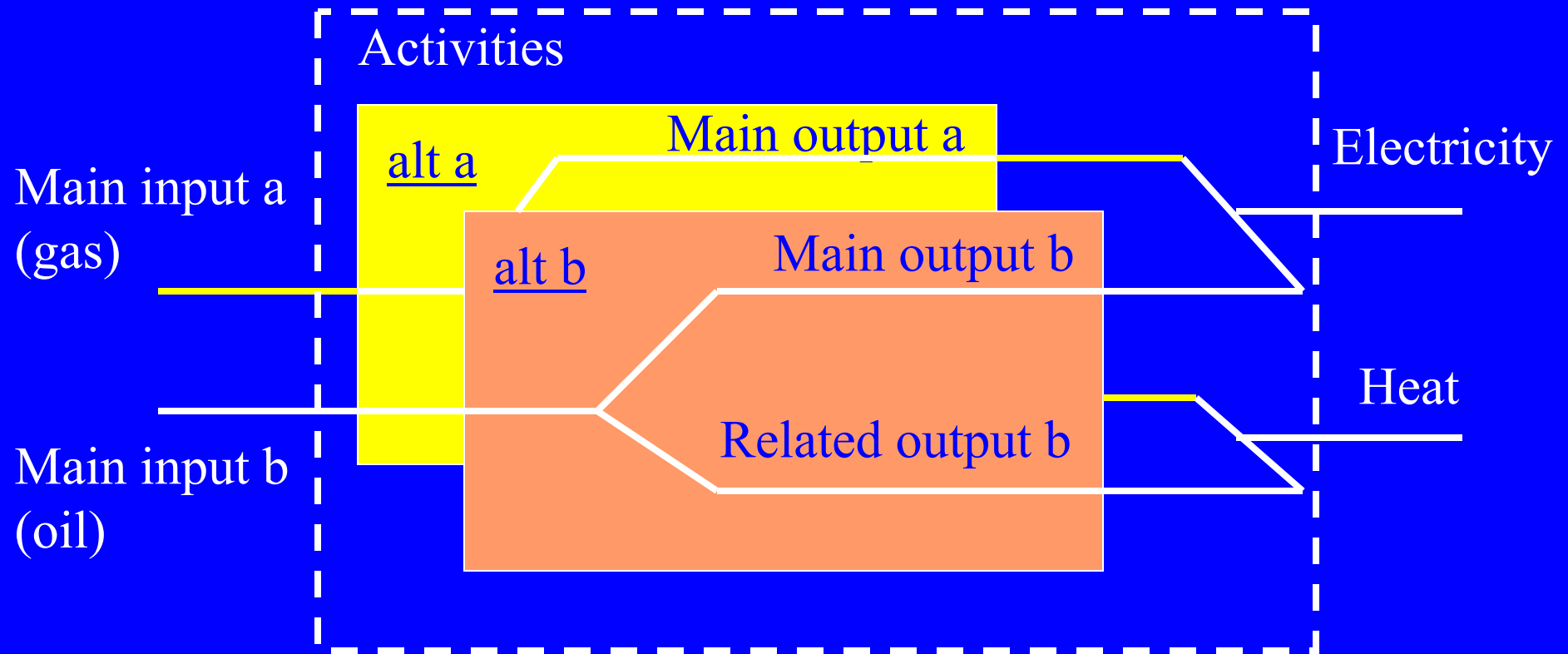
multiple entries:

abda	bda	con1a	con2a	conca	conpa	consa
corin	corout	inp	mlocst	mlolim	mpa	mupost
	outp	shrT	shra	shrt		

description:

Representation of CHP in MESSAGE

Multi fuel back pressure unit



Technical parameters of CHP's

Extraction units

Nominal electrical capacity in CHP mode (P_n),

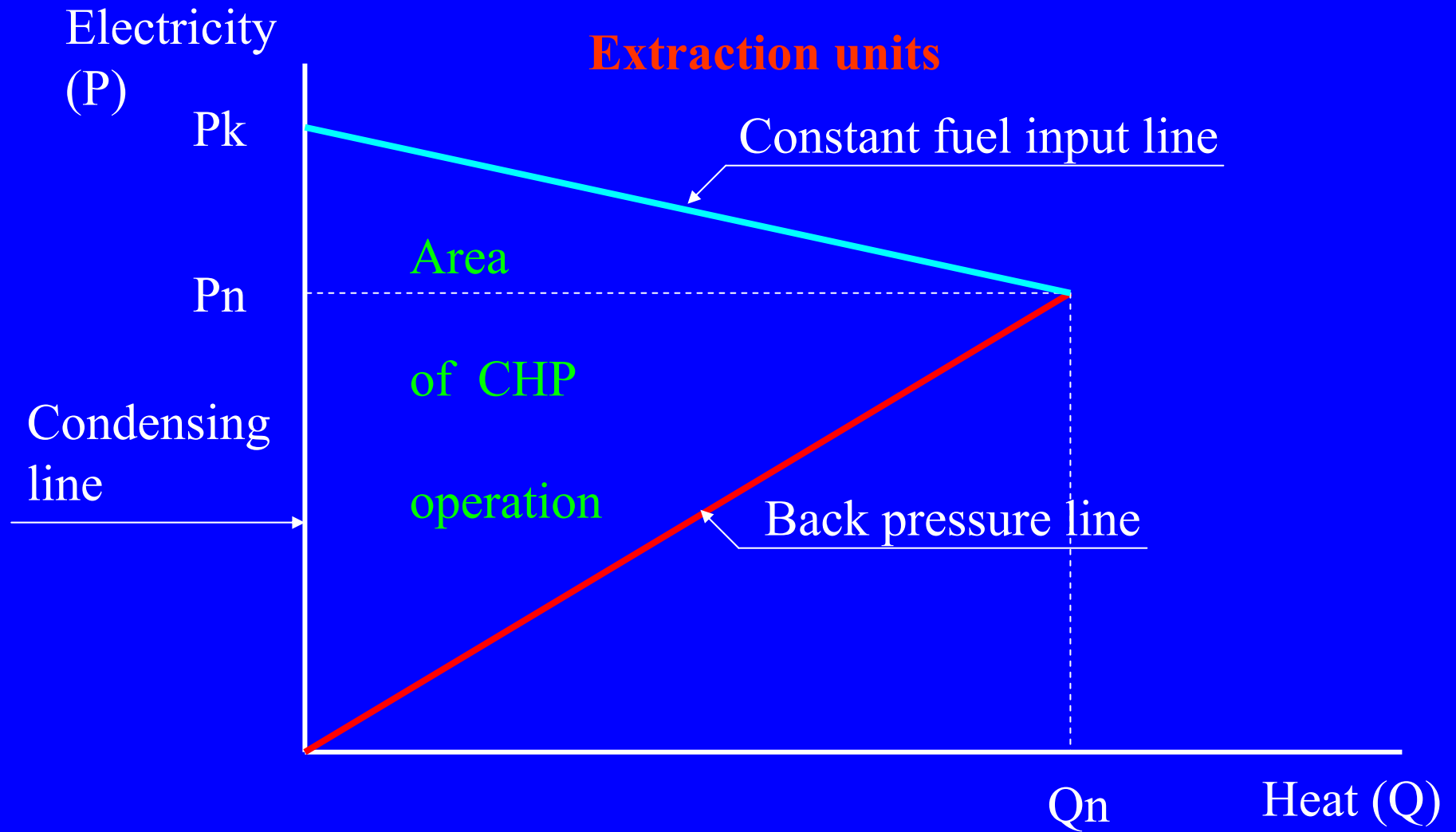
Nominal electrical capacity in condensing mode (P_k),

Nominal thermal capacity (Q_n),

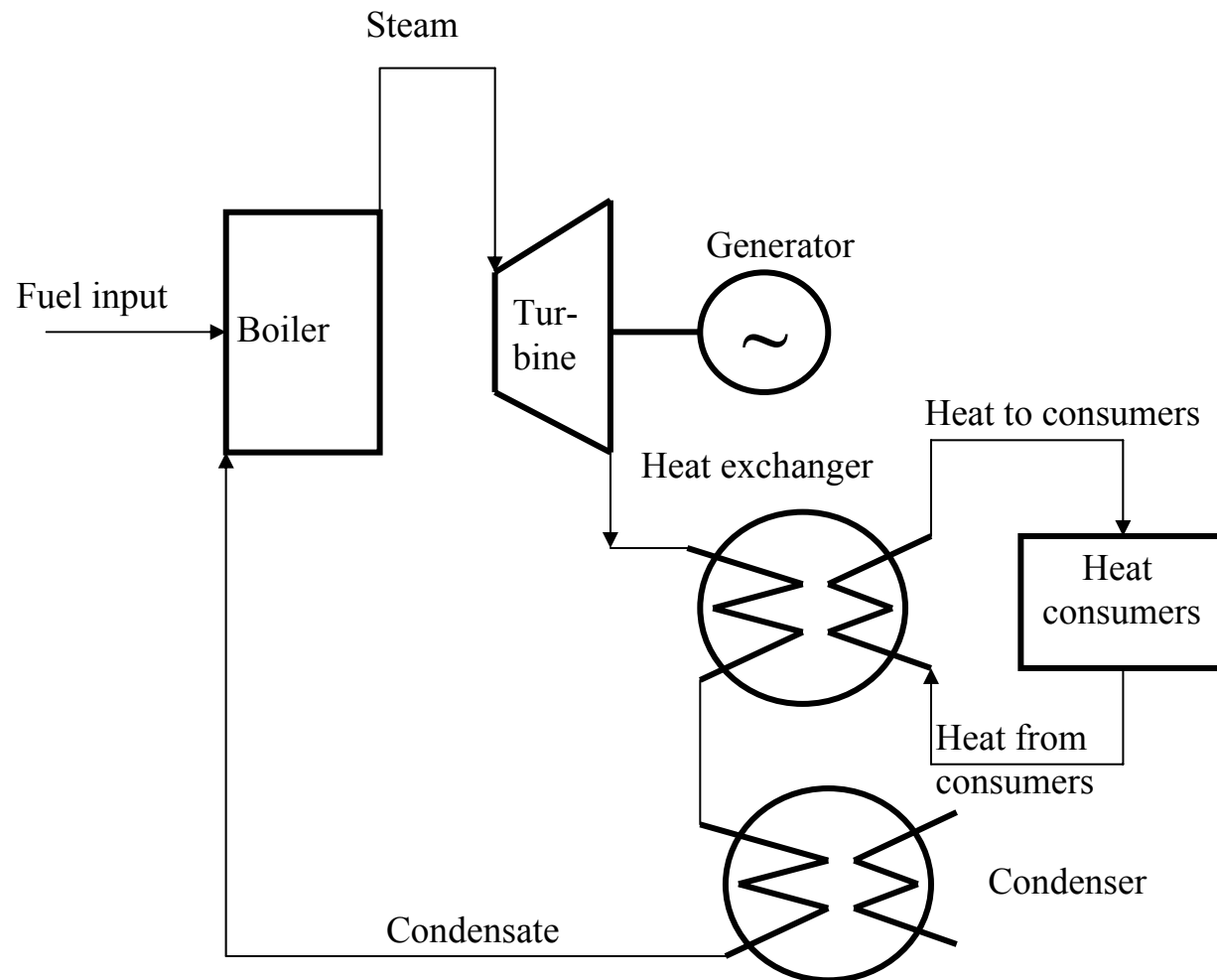
Fuel efficiency in condensing mode (η_k),

Fuel efficiency in CHP mode (Total efficiency) (η_T).

Relation between heat and electricity output

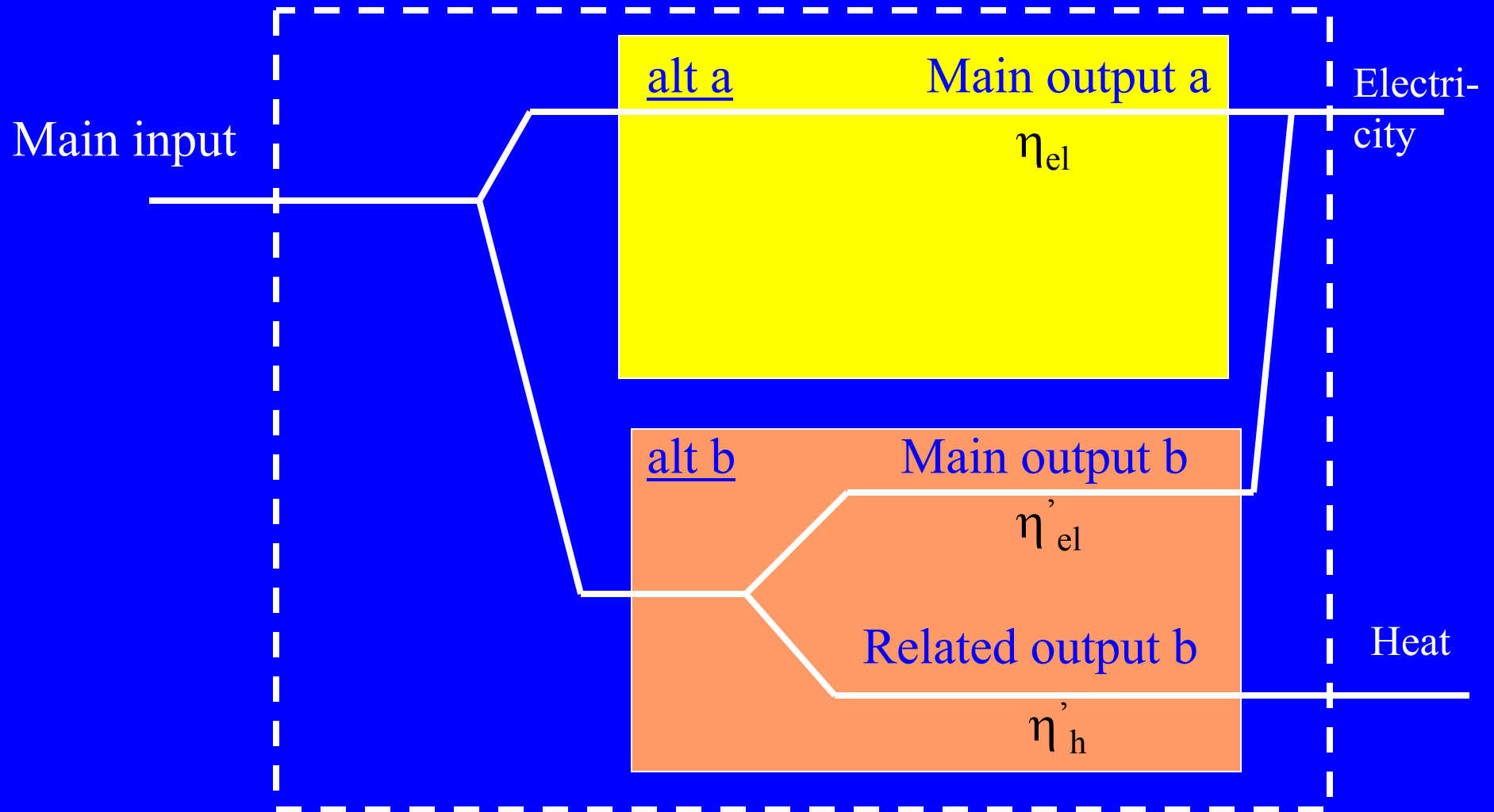


Extraction unit



Representation of CHP in MESSAGE

Extraction unit (single fuel)



Representation of CHP in MESSAGE

Extraction unit (single fuel)

$P_n = 171.8$ MW; $P_k = 208$ MW; $Q_n = 302.3$ MW;

$\eta_k = 0.357$; $\eta_T = 0.81$;

$$\eta_{el} = \eta_k = 0.357; \text{ (Power relation) pow.rel.} = \frac{P_k}{P_n} = \frac{208}{171.8} = 1.21;$$

$$\eta'_{el} = \frac{P_n}{(P_n + Q_n)/\eta_T} = \frac{171.8}{(171.8+302.3)/0.81} = 0.293;$$

$$\eta'_h = \frac{Q_n}{(P_n + Q_n)/\eta_T} = \frac{302.3}{(171.8+302.3)/0.81} = 0.516;$$

Representation of CHP in MESSAGE

Extraction unit (single fuel)

The image displays two screenshots of the MESSAGE software interface, illustrating the configuration of a CHP (Combined Heat and Power) technology. The left screenshot shows the 'Technologies' window with the following parameters and callouts:

- Pk=208**: A callout pointing to the 'pk' field in the 'multiple entries' table.
- alt a**: A callout pointing to the 'alt' field in the 'activities' table.
- $\eta_{el}=0.357$** : A callout pointing to the 'var costs' field in the 'single entries' table.
- pow.rel.=1.0**: A callout pointing to the 'pow rel' field in the 'single entries' table.

The right screenshot shows the 'Technologies' window with the following parameters and callouts:

- alt b**: A callout pointing to the 'alt' field in the 'activities' table.
- $\eta'_h=0.516$** : A callout pointing to the 'Heat_Vinrus_area/output' field in the 'secondary outputs' table.
- $\eta'_{el}=0.293$** : A callout pointing to the 'Electricity_high_voltage/it' field in the 'secondary outputs' table.
- pow.rel.=1.21**: A callout pointing to the 'pow rel' field in the 'single entries' table.

An orange arrow points from the left screenshot to the right one, indicating a transition or comparison between the two configurations.

Cost data of CHP's

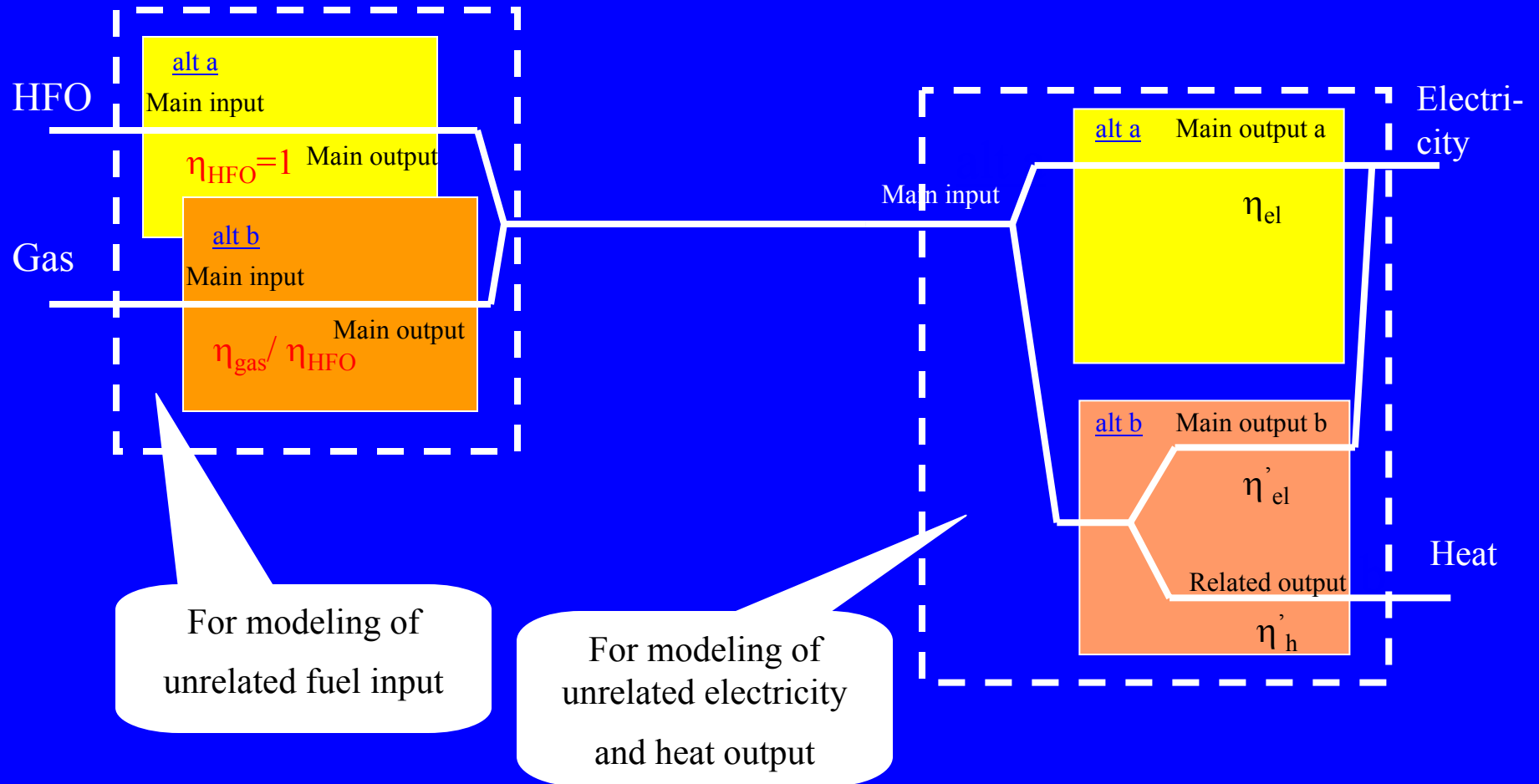
Extraction units

Investment costs and fixed O&M costs are related to power capacity in condensing mode,

Variable O&M costs are related to electricity output
In condensing regime.

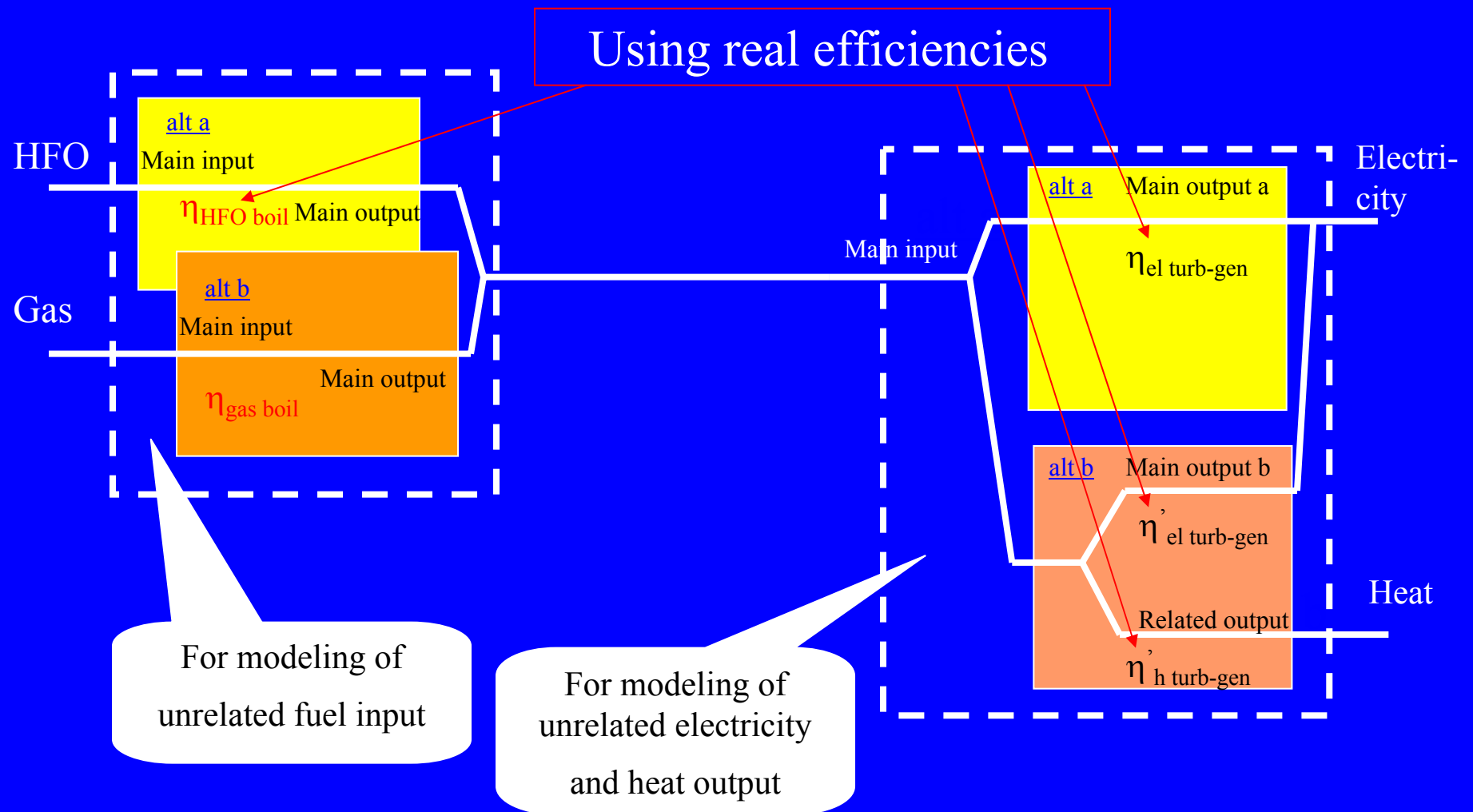
Representation of CHP in MESSAGE

Extraction unit (multiple fuel)

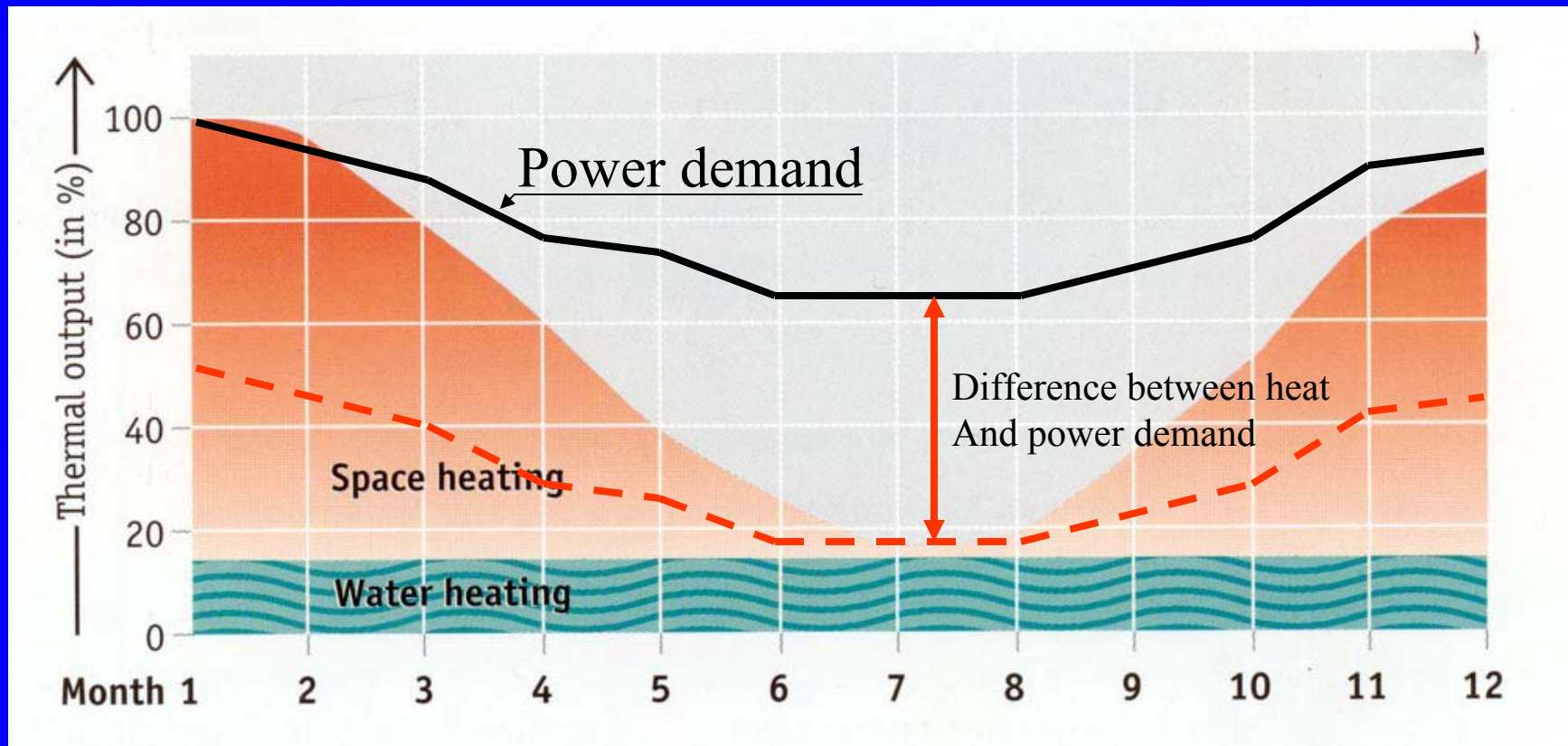


Representation of CHP in MESSAGE

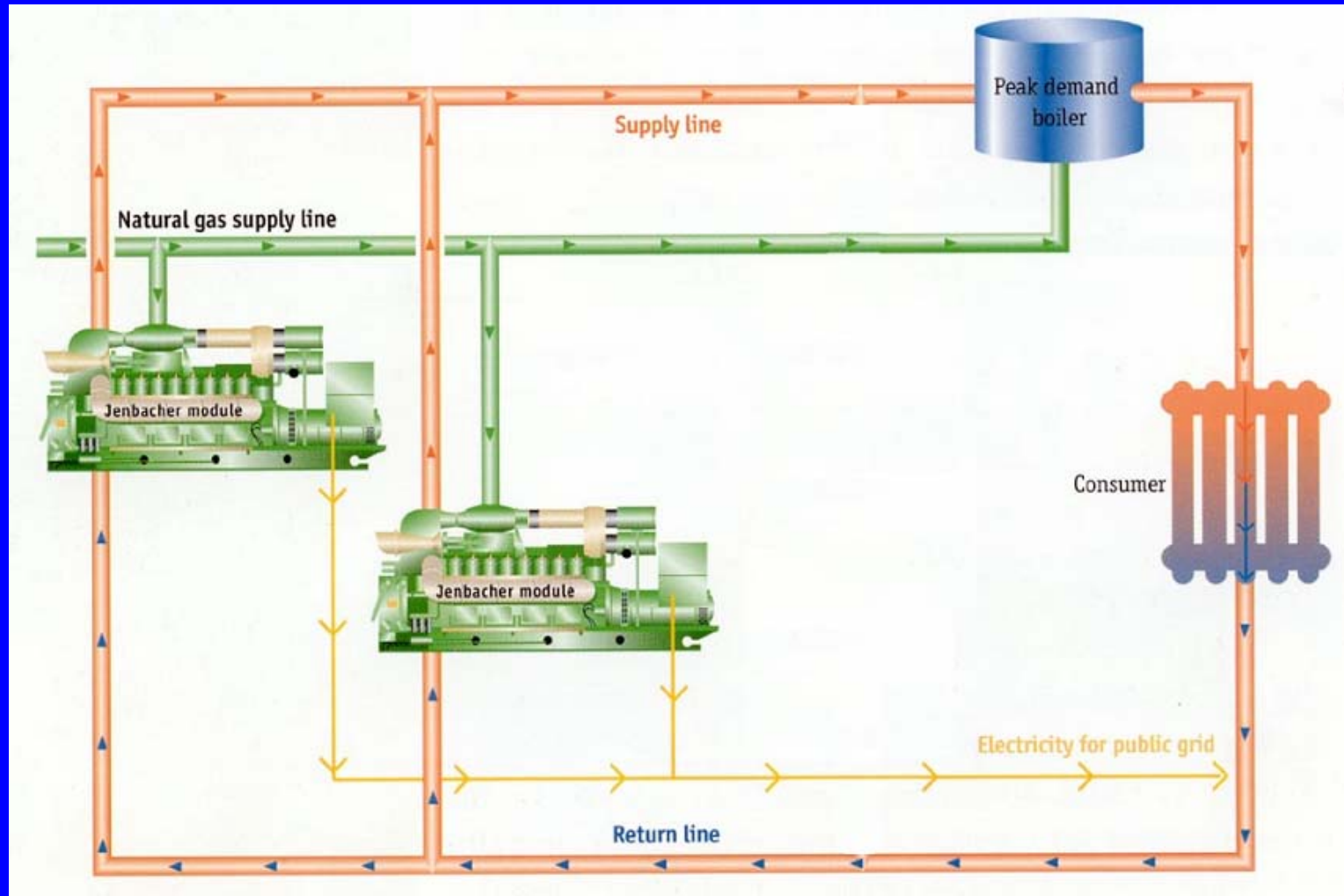
Extraction unit (multiple fuel)



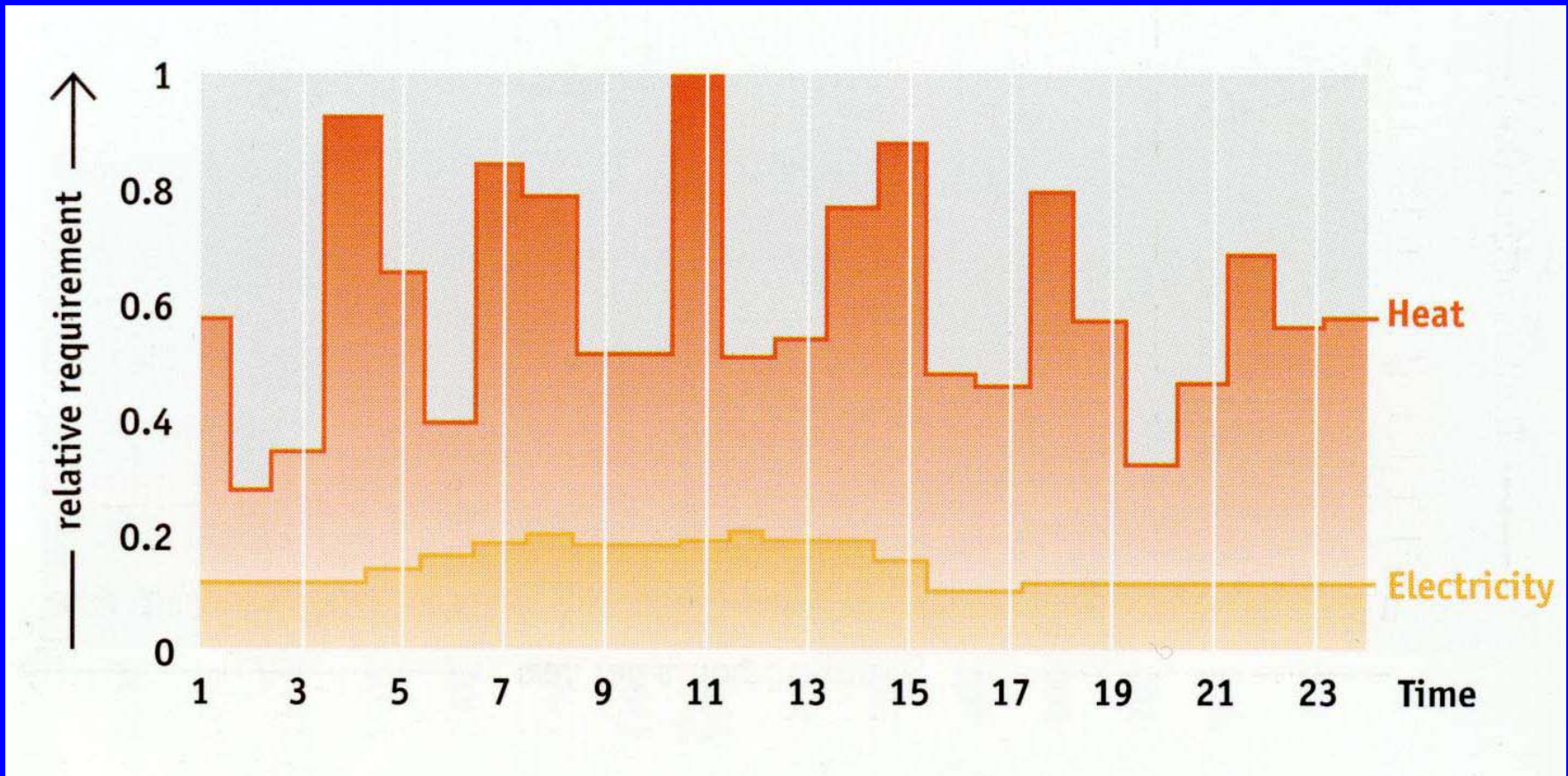
Ability of CHP to cover heat and power demand



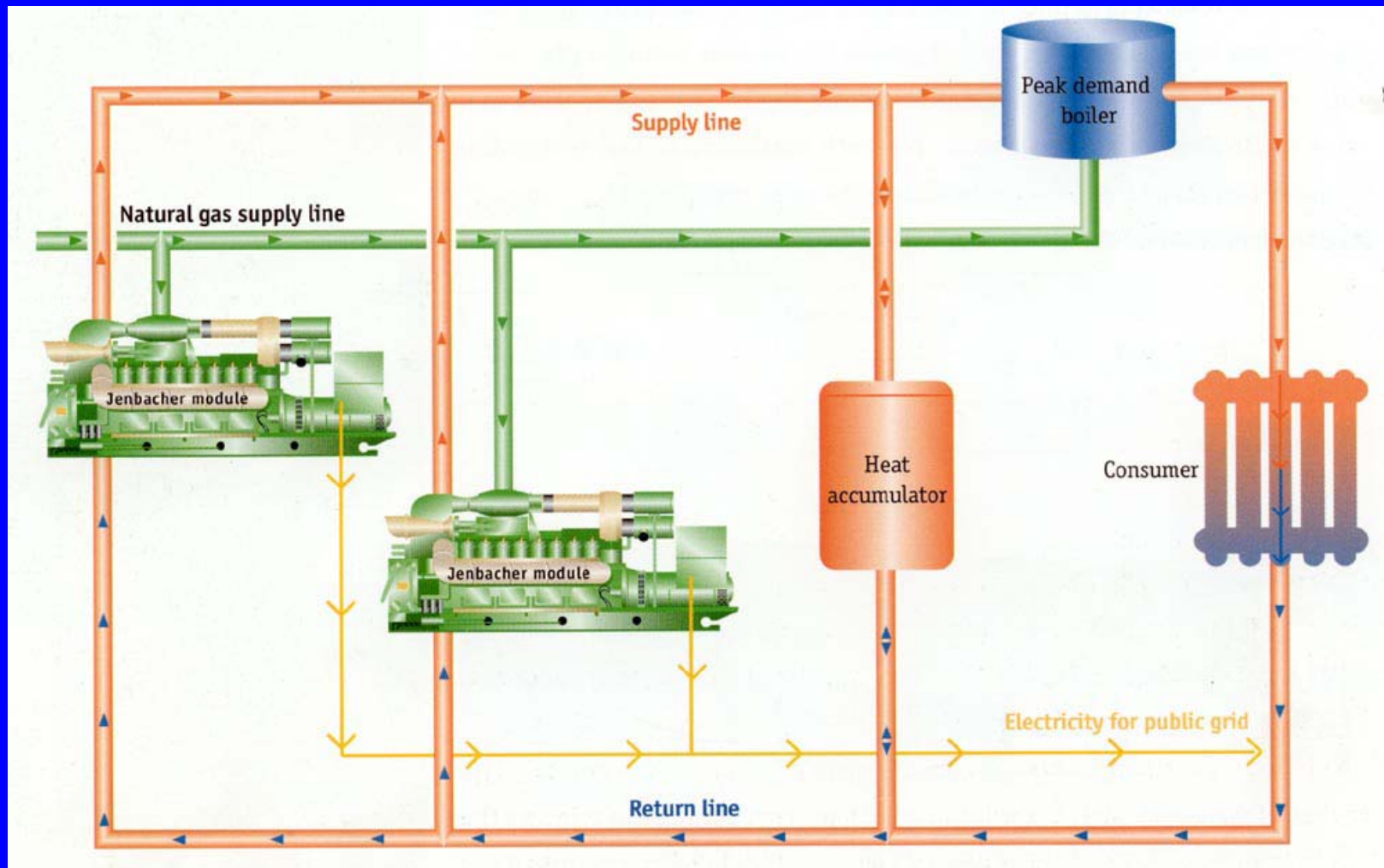
Joining of CHP's with heat only boilers



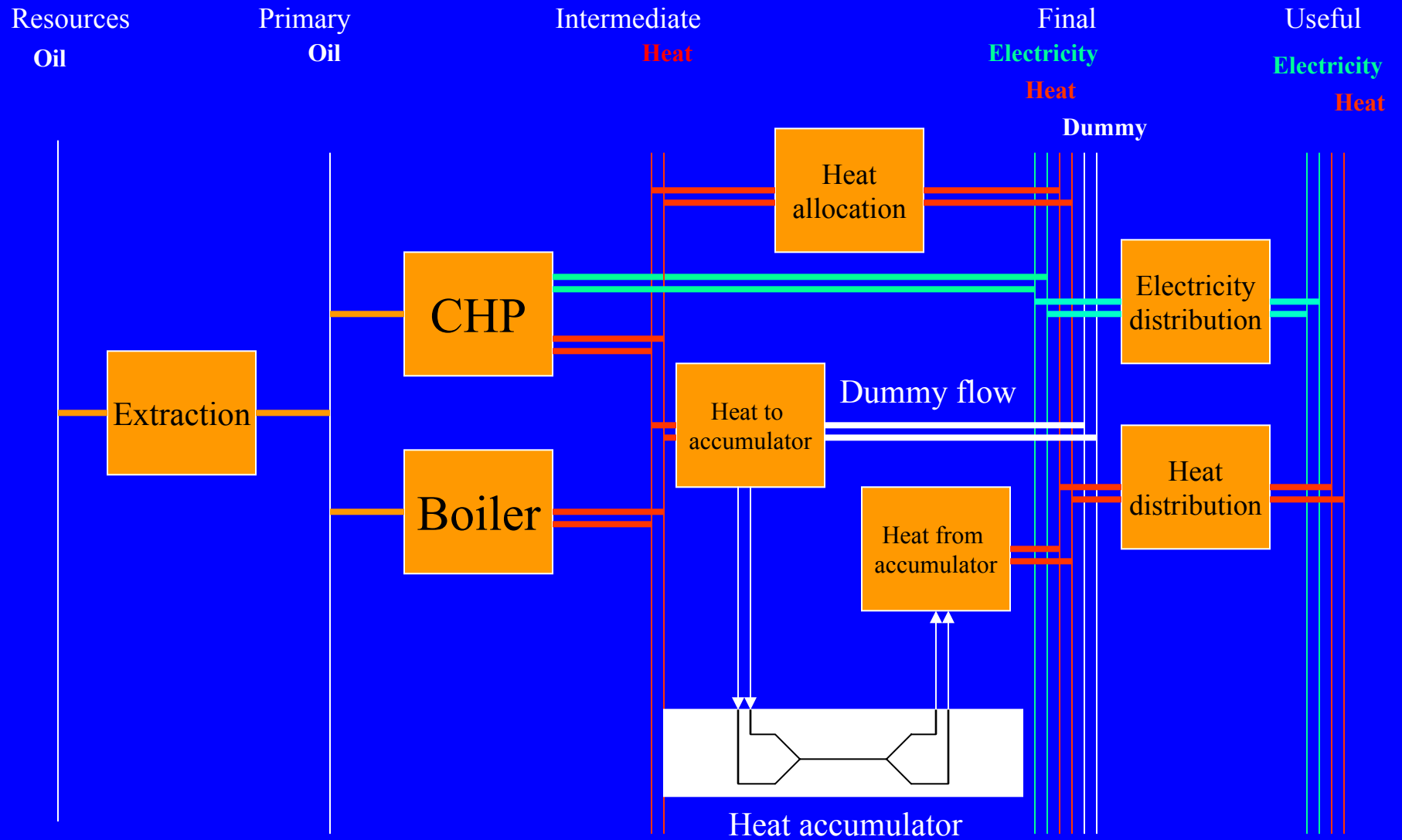
Heat load fluctuations



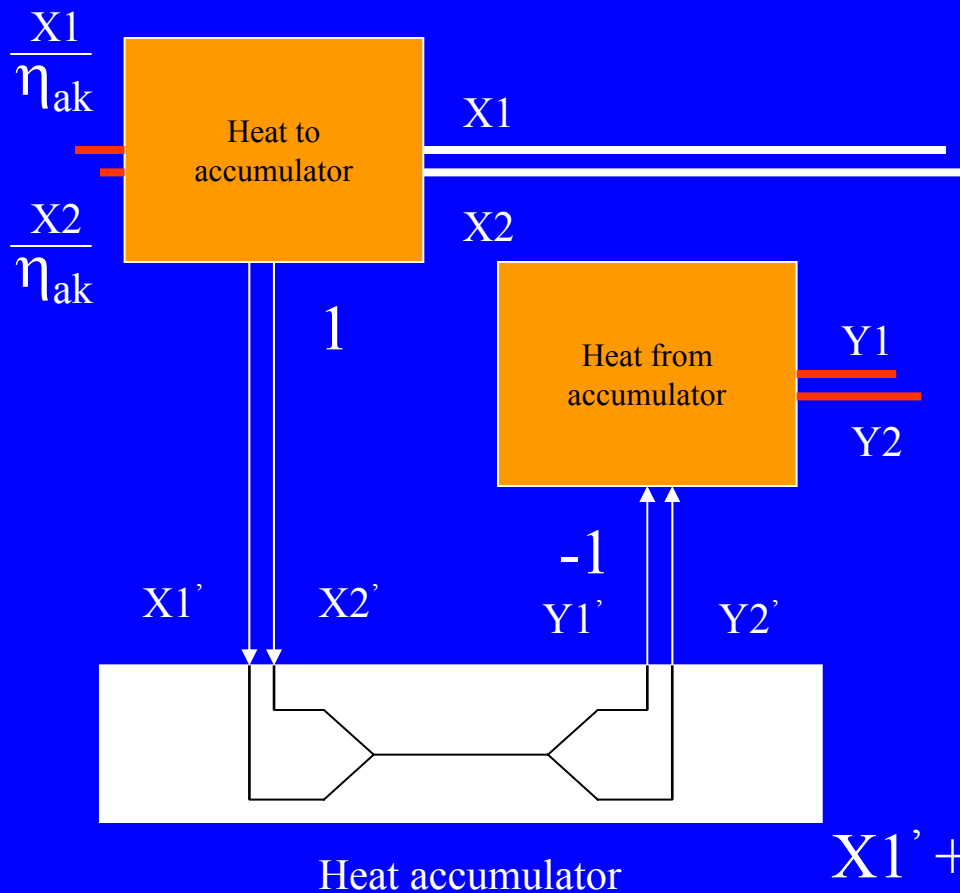
CHP with heat accumulator



Modeling of CHP with heat storage



Principle equations for heat accumulator



$$X1' = X1; \quad X2' = X2;$$

$$Y1 = Y1'; \quad Y2 = Y2';$$

$$X1' - Y1' \leq \text{active volume};$$

$$X1' + X2' - Y1' - Y2' \leq \text{active volume};$$

Data sheet for heat accumulator

74 IAEA - MESSAGE chptest adb

Screen

General

Load regions

Energyforms

Demands

Constraints

Technologies

Resources

Constraints / Relations

group: storage relation: heat accum

Entries Add from TDB New

Storage technologies

single entries

storage name: Heat_accum storage short name: heat rel to input/output: loadcurves for: cost

storage type: daily

Unit	Switch	Time series
storage cost: \$'00/kWyr	<input type="checkbox"/>	10
max volume: MWyr	<input type="checkbox"/>	200
min volume: MWyr	<input type="checkbox"/>	60

first year: initial volume: last year: volume:

multiple entries

inflow outflow overflow penalty softlims

description

1 step
"Constraints"

2 step
"Storage"

3 step
"New"

Short name of
relation for
heat
accumulation

4 step Fill
data

Technology “Heat to accumulator”

IAEA - MESSAGE chptest adb

Screen

Technologies

input: all
output: all
relations: all
name (re):
has inv: all yes no
operator: and or
technologies: Heat_to_accum

activities

Add
alt a
alt

single entries

	Name	Unit	Value	loadcurves for:
main input	oil/primary	kWyr	1.0	moutp
	heat/final	kWyr	c 1	

var costs: \$'00/kWyr
Unit: \$'00/kWyr
Switch:
Time series:

hist. act.: MWyr
Unit: MWyr
Value:
pow. rel.:

multiple entries

abda bda con1a con2a conca conpa **consa**

Heat to accumulator

Name of relation for heat accumulation

Input and output according your network

1

Efficiency of heat storage

Technology “Heat from accumulator”

The screenshot shows the IAEA MESSAGE software interface for configuring a technology. The main window is titled "Technologies" and contains several sections:

- General:** Includes input, output, and relations dropdown menus, all set to "all". It also has radio buttons for "has inv" (all, yes, no) and "operator" (and, or).
- Technologies:** A dropdown menu is set to "Heat_from_accum".
- activities:** A sub-window titled "Heat_to_accum relations consa" is open, showing "Linked storage constraints on activities". It has a "relation" dropdown set to "heat" and a "Data" field with a value of "-1".
- single entries:** A table with columns for Name, Unit, and Value. The first row is "heat/final" with unit "kWyr" and value "1".
- multiple entries:** A row of buttons labeled "abda", "bda", "con1a", "con2a", "conca", "conpa", and "consa". The "consa" button is highlighted in green.

Annotations on the screenshot:

- A callout bubble points to the "Heat_from_accum" dropdown with the text "Heat_from accumulator".
- A callout bubble points to the "heat" dropdown in the activities window with the text "Name of relation for heat accumulation".
- A callout bubble points to the "-1" value in the activities window with the text "-1".
- A callout bubble points to the "1" value in the single entries table with the text "1".
- A callout bubble points to the "consa" button with the text "Output according your network".

Parameters of small back pressure CHP based on natural gas

		Cento 42 AP	Cento 65 AP	Cento 75 AP	Cento 100 SP	Cento 140 SP	Plus twin 44 AP	Plus twin 88 AP	Premi 22 AP	Premi vari 22 AP
Electrical capacity	kW	42	65	75	100	150	44	88	22	22
Thermal capacity	kW	64,5	97	125	161	226	91	182	45,5	45,5
Input (fuel) capacity	kW	124	189	244	305	430	155	310	77,5	77,5
Efficiency (electrical)	%	33,8	34,4	30,7	32,8	34,8	28,4	28,4	28,4	28,4
Efficiency (thermal)	%	52,0	51,3	51,2	52,8	52,8	58,8	58,8	58,8	58,8
Efficiency (total)	%	85,8	85,7	81,9	85,6	87,4	87,2	87,2	87,2	87,2
Gas consumption at 100% capacity	m ³ /h	13,2	20,0	25,8	32,3	45,5	16,4	32,8	8,2	8,2
Gas consumption at 75% capacity	m ³ /h	10,8	16,3	20,6	26,8	39,8	13,2	26,4	6,6	6,6
Gas consumption at 50% capacity	m ³ /h	8,3	12,5	16,4	20,3	31,5	10,4	20,8	5,2	5,2
Temperature of water input/output	°C	70/90	70/90	70/90	70/90	70/90	70/90	70/90	70/90	70/90
Investment cost	K\$	43.800	52.300	44.200	68.000	82.800	25.000	50.000	12.500	11.500