



Technische Universität Berlin

Institute for Energy Engineering



Minimization of Costs and Environmental Impact Using Exergy-Based Methods

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Introduction - 1

The objective evaluation and the improvement of an energy conversion system from the viewpoints of ***thermodynamics***, ***economics***, and ***environmental impact*** require a deep understanding of

- the ***real thermodynamic inefficiencies*** and the processes that cause them,
- the ***costs associated with equipment and thermodynamic inefficiencies*** as well as the connection between these two important factors,
- the ***environmental impact associated with equipment and thermodynamic inefficiencies*** as well as the connection between these two sources of environmental impact,
- the ***interconnections among efficiency, investment cost and component-related environmental impact*** associated with the selection of specific system components, and
- possible ***measures*** that would improve the efficiency and the cost effectiveness and would reduce the environmental impact of the system being studied.

Introduction - 2

Energy-based methods are not suitable for answering these questions because the only thermodynamic inefficiencies identified by energy-based methods are the transfer of energy to the environment. However, *the inefficiencies caused by the irreversibilities within the system* being considered are, in general, by far the most important thermodynamic inefficiencies and are identifiable with the aid of an exergetic analysis.

If we want to successfully reduce thermodynamic inefficiencies, cost and environmental impacts in a system we must first understand their formation process. *Exergy-based methods* reveal the location, the magnitude and the sources of inefficiencies, costs and environmental impact and allow us to study the interconnections between them.

Exergy-Based Methods - 1

Exergy-based methods is a general term that includes the conventional and advanced *exergetic*, *exergoeconomic*, and *exergoenvironmental analyses* and evaluations.

The *concept of exergy* complements and enhances an energetic analysis by calculating

- (a)** the true thermodynamic value of an energy carrier,
- (b)** the real thermodynamic inefficiencies in a system, and
- (c)** variables that unambiguously characterize the performance of a system (or one of its components) from the thermodynamic viewpoint.

Exergoeconomic analysis

An ***exergoeconomic analysis*** (term proposed for the first time in 1984) consists of an exergetic analysis, an economic analysis, and an exergoeconomic evaluation.

Exergoeconomics is based on the ***exergy costing principle***, which states that exergy is the only rational basis for assigning monetary values to energy streams and to the thermodynamic inefficiencies within the system.

Mass, energy or entropy should not be used for assigning monetary values because their exclusive use results in misleading conclusions.

Economic Analysis

Each Institution uses its own method for conducting an economic analysis.

An ***economic analysis*** should be conducted for the entire life of the system being considered. In this analysis, all pertinent costs should be considered. These include depreciation, return on debt and equity, taxes and insurance, fuel costs and operating and maintenance expenses. To obtain a representative year of system operation, all costs are levelized.

Cost Sources

The real cost sources (identifiable only by exergoeconomics) in an energy conversion system are the:

- capital investment for each component
- operating and maintenance expenses
- cost of exergy destruction
- cost of exergy loss from the overall system

Exergoenvironmental analysis

An ***exergoenvironmental analysis*** (presented for the first time in 2006) consists of an exergetic analysis, a life cycle assessment (LCA) of the environmental impact and an exergoenvironmental evaluation conducted in analogy with the exergoeconomic one.

The ***exergoenvironmental costing principle*** which is used in an exergoenvironmental analysis, states that exergy is the only rational basis for assigning environmental impact to energy streams and to the thermodynamic inefficiencies within a system.

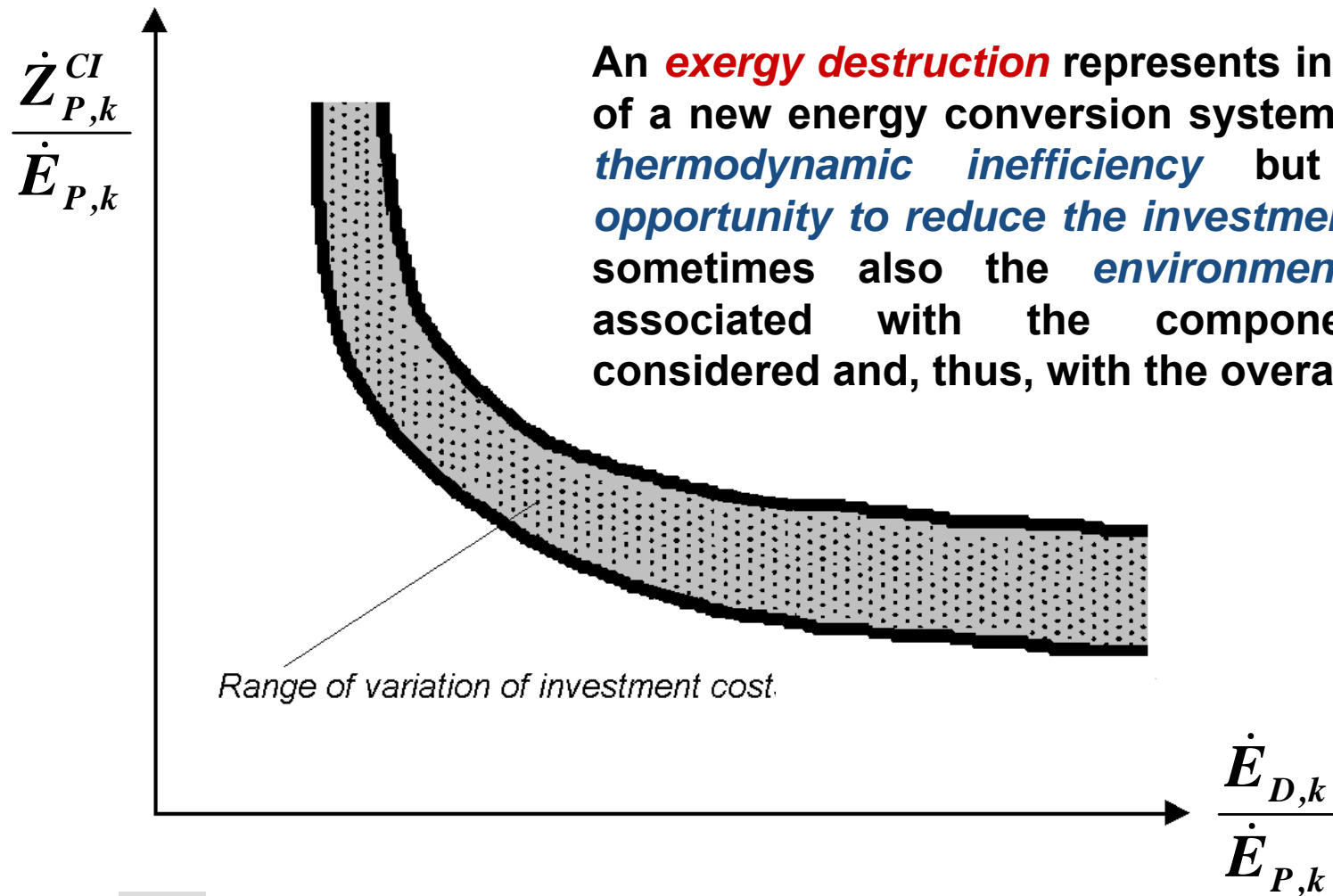
Life Cycle Assessment

The total system used to conduct the LCA includes the supply of the input streams, especially the fuel, and the full life cycle of components. Inventories of elementary flows – i.e., consumption of natural resources and energy as well as emissions - are compiled following the guidelines of international standard approaches.

An impact assessment is performed using an environmental indicator (e.g., the *Eco-indicator 99*, which is based on the definition of three damage categories, human health, ecosystem quality and natural resources).

The result is expressed as *Eco-indicator points (pts)*.

Iterative improvement



An **exergy destruction** represents in the design of a new energy conversion system not only a **thermodynamic inefficiency** but also an **opportunity to reduce the investment cost** and sometimes also the **environmental impact** associated with the component being considered and, thus, with the overall system.

Advanced Exergy-Based Analyses

The *conventional exergetic, exergoeconomic, and exergo-environmental* analyses do not evaluate the mutual interdependencies among the system components nor the potential for improving a component.

These issues are considered in the *advanced analyses*, in which the *exergy destruction, capital investment cost and construction-of-component-related environmental impact* in each component are split into:

- *Endogenous* and *exogenous* parts,
- *Unavoidable* and *avoidable* parts, and
- The resulting combined parts.

Definition of $\dot{E}_{D,k}^{EN}$ and $\dot{E}_{D,k}^{EX}$

The *endogenous* exergy destruction in a component ($\dot{E}_{D,k}^{EN}$) refers to the irreversibility occurring within this component when all other components operate in an ideal way and the component being considered operates with its current efficiency.

The *exogenous* exergy destruction ($\dot{E}_{D,k}^{EX}$) is caused in the k -th component by the irreversibilities that occur in the remaining components.

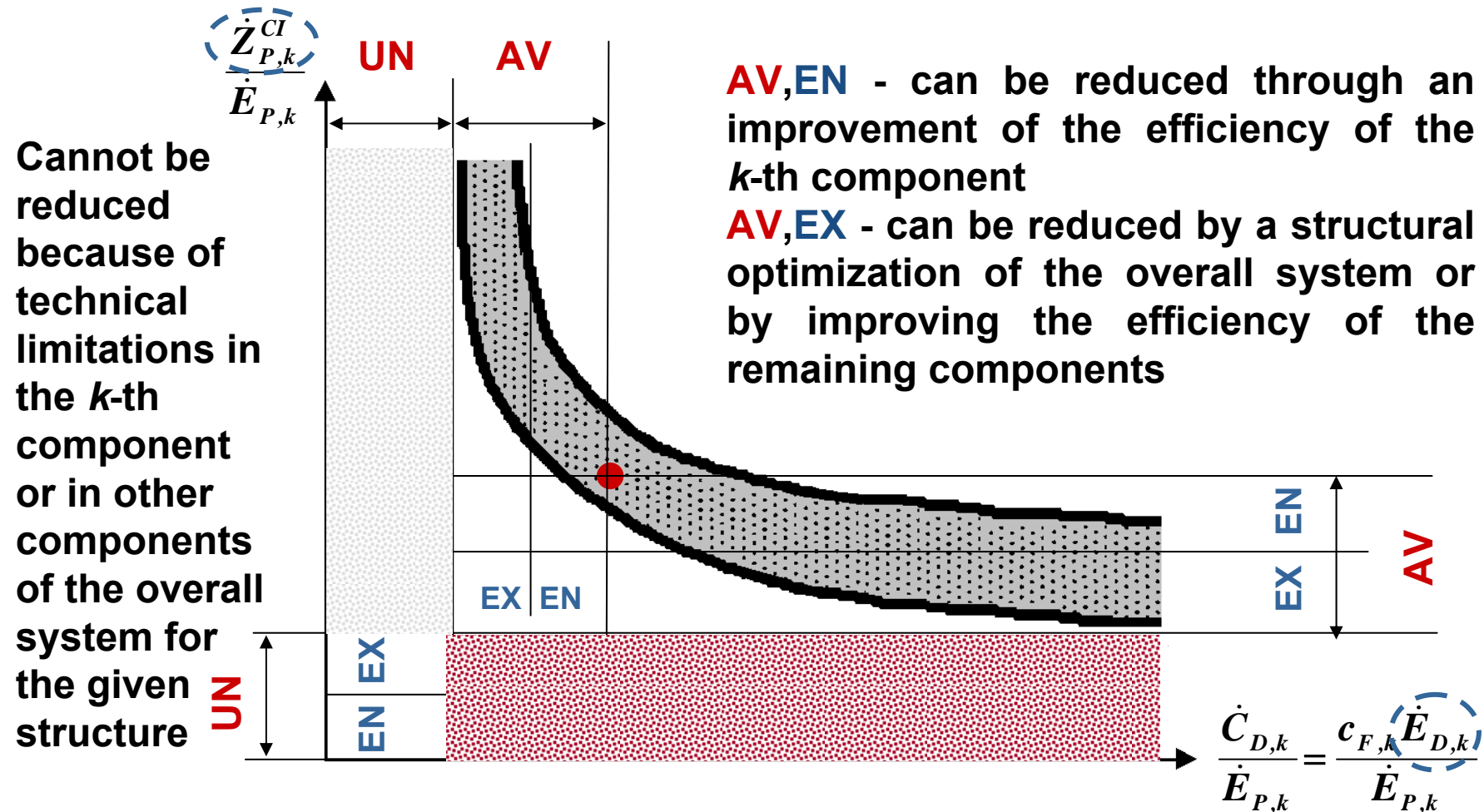
$$\dot{E}_{D,k} = \dot{E}_{D,k}^{EN} + \dot{E}_{D,k}^{EX}$$

Definition of $\dot{E}_{D,k}^{UN}$ and $\dot{E}_{D,k}^{AV}$

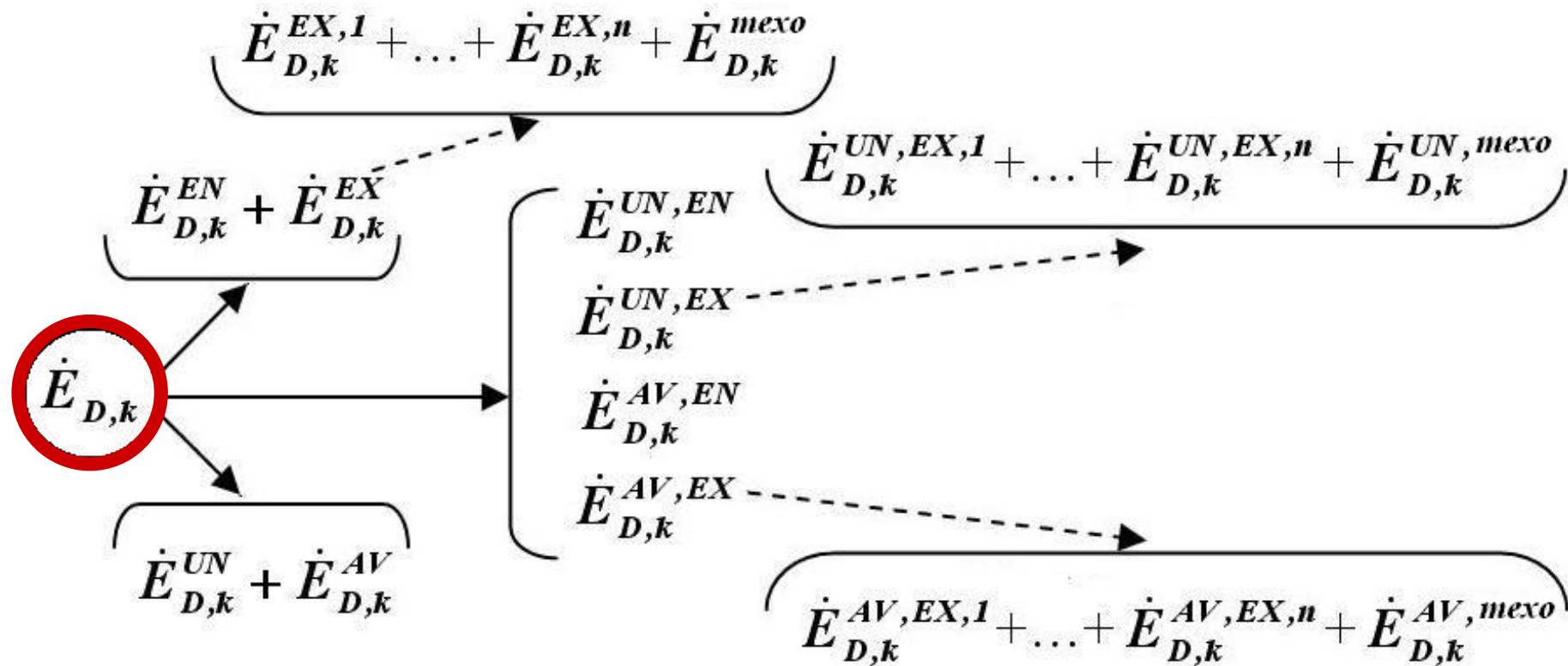
Unavoidable ($\dot{E}_{D,k}^{UN}$) is the exergy destruction in a component that will always be there as long as this component is being used in the system, i.e. the unavoidable exergy destruction cannot be reduced because of technological limitations such as availability and cost of materials and manufacturing methods.

The **avoidable** exergy destruction ($\dot{E}_{D,k}^{AV}$) can be varied during efforts to improve the cost effectiveness of the component and the overall system.

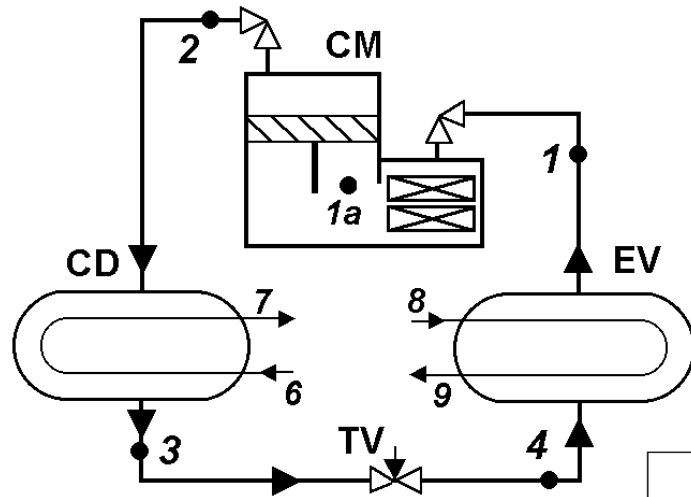
Graphical Representation



Splitting the Exergy Destruction



Example: Refrigeration machine



$$Q_{cold} = 50 \text{ kW}$$

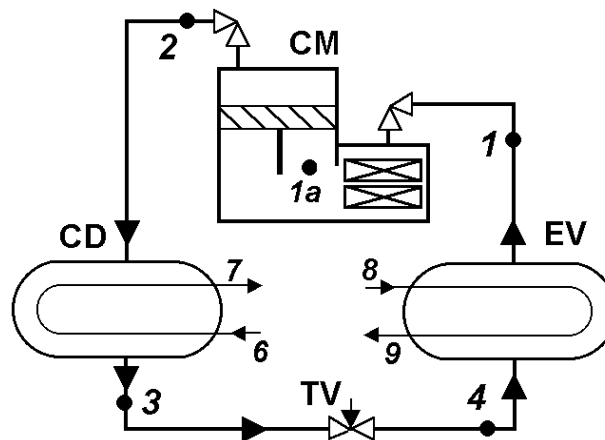
Working fluid: R134a

Water: $T_8 = 5^\circ\text{C}$ und $T_9 = 12^\circ\text{C}$

Water: $T_6 = 20^\circ\text{C}$ und $T_7 = 25^\circ\text{C}$

Stream	Working fluid	Thermodynamic analysis			
		\dot{m} [kg/s]	T [K]	p [bar]	e [kJ/kg]
1	R134a	0.3247	0	2.93	25.3
1a	R134a	0.3247	10	2.93	24.8
2	R134a	0.3247	49	8.16	47.5
3	R134a	0.3247	32	8.16	39.6
4	R134a	0.3247	0	2.93	36.6
6	Water	2.939	20	1.50	0.05
7	Water	2.939	25	1.42	0.22
8	Water	1.704	12	1.50	0.51
9	Water	1.704	5	1.42	1.71

Example: Refrigeration machine



Component	$\dot{E}_{F,k}^{real}$ [kW]	$\dot{E}_{P,k}^{real}$ [kW]	$\dot{E}_{D,k}^{real}$ [kW]	ε_k [%]	γ_k [%]
CM	8.554	7.381	1.173	86.3	13.7
CD	2.573	0.496	2.077	-	24.3
TV	4.858	3.864	0.994	79.5	11.6
EV	3.657	2.031	1.626	55.5	19.0

Example: Conventional Analyses

Conventional exergoeconomic analysis

Component	PEC_k [€]	\dot{Z}_k [€ cent/h]	$\dot{C}_{D,k}$ [€ cent/h]	$\dot{Z}_k + \dot{C}_{D,k}$ [€ cent/h]	$c_{F,k}$ [€/GJ]	$c_{P,k}$ [€/GJ]	r_k [-]	f_k [%]
CM	9 370	14.3	13.8	28.1	32.61	44.10	0.35	50.90
CD	1 843	2.8	33.6	36.4	45.02	249.10	4.53	7.71
TV	50	0.1	15.8	15.9	44.10	55.50	0.26	0.48
EV	1 787	2.7	32.5	35.2	55.50	103.70	0.87	7.74

Conventional exergoenvironmental analysis

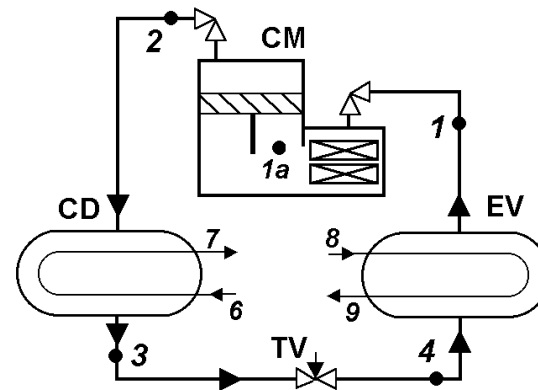
Component	Y_k [mPts]	\dot{Y}_k [mPts/h]	$\dot{B}_{D,k}$ [mPts /h]	$\dot{Y}_k + \dot{B}_{D,k}$ [mPts /h]	$b_{F,k}$ [mPts /GJ]	$b_{P,k}$ [mPts /GJ]	$r_{b,k}$ [-]	$f_{b,k}$ [%]
CM	44 986	0.348	15.25	15.60	3 611	4 289	0.19	2.23
CD	108 382	0.838	32.72	33.56	4 377	23 160	4.29	2.50
TV	172	0.001	15.34	15.35	4 289	5 392	0.26	<0.01
EV	94 320	0.729	31.56	32.29	5 392	9 808	0.82	2.26

Example: Advanced Exergetic Analysis

Advanced exergetic analysis for the vapor-compression refrigeration machine

Com- ponent	$\dot{E}_{D,k}^{EN}$ [W]	$\dot{E}_{D,k}^{EX}$ [W]		$\dot{E}_{D,k}^{UN}$ [W]	$\dot{E}_{D,k}^{AV}$ [W]	Splitting $\dot{E}_{D,k}^{real}$ [W]								
						$\dot{E}_{D,k}^{UN}$			$\dot{E}_{D,k}^{AV}$					
						$\dot{E}_{D,k}^{UN,EN}$	$\dot{E}_{D,k}^{UN,EX}$		$\dot{E}_{D,k}^{AV,EN}$	$\dot{E}_{D,k}^{AV,EX}$				
CM	677	496	CD	256	371	802	203	168	CD	85	474	328	CD	171
			TV	6					TV	2			TV	4
			EV	208					EV	68			EV	140
			mexo	26					mexo	13			mexo	13
CD	1 799	278	CM	60	640	1 437	588	52	CM	10	1 211	226	CM	50
			TV	24					TV	8			TV	16
			EV	150					EV	27			EV	123
			mexo	44					mexo	7			mexo	37
TV	373	621	CD	0	545	449	373	172	CD	0	0	449	CD	0
			CM	334					CM	23			CM	311
			EV	202					EV	149			EV	53
			mexo	85					mexo	0			mexo	85
EV	1 626	0		756	870	756	0	870	0					

Example: Refrigeration machine



Summary of the results obtained from the advanced exergy-based analyses.

Component	Advanced exergetic analysis	Advanced exergoeconomic analysis			Advanced exergoenvironmental analysis		
	$\dot{B}_{D,k}^{AV,S}$ [W]	$\dot{Z}_k^{AV,S}$ [cent/h]	$\dot{C}_{D,k}^{AV,S}$ [cent/h]	$\dot{C}_{D,k}^{AV,S} + \dot{Z}_k^{AV,S}$ [cent/h]	$\dot{Y}_k^{AV,S}$ [mPts/h]	$\dot{B}_{D,k}^{AV,S}$ [mPts/h]	$\dot{B}_{D,k}^{AV,S} + \dot{Y}_k^{AV,S}$ [mPts/h]
CM	835	5.6	11.31	16.91	0.088	11.752	11.840
CD	1382	3.2	21.63	24.83	0.098	21.305	21.403
TV	20	0	1.90	1.90	0.040	2.072	2.112
EV	1133	3.9	21.85	25.75	0.062	21.463	21.525

Closure - 1

The *methods* discussed here *enable* engineers to

- calculate the flow of exergy, cost and environmental impact through the plant
- identify the real sources of thermodynamic inefficiencies, costs, and environmental impacts
- calculate the cost and the environmental impact associated with exergy destruction at the component level
- decide about well justified design changes

Closure - 2

With these methods

- a plant can be analyzed in a consistent way from the viewpoints of *thermodynamics*, *economics* and *environmental impact*
- the connections between thermodynamics and economics are revealed, and
- the interactions among plant components and the potential for improving a component and the overall system are also identified.

The connections between environmental impact on one side and thermodynamics or economics on the other side still need to be studied.

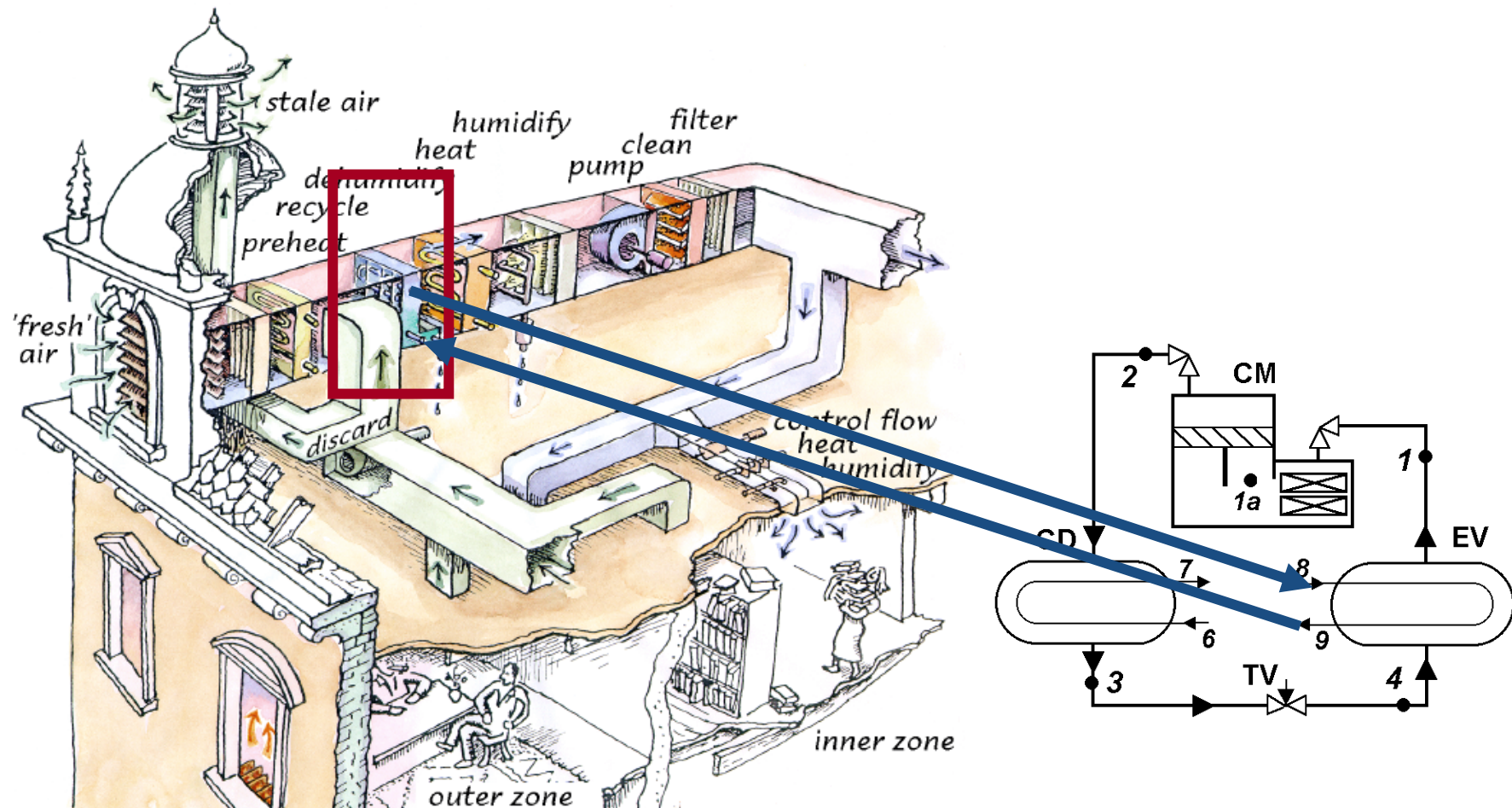
With the methods presented here

- **our understanding of what is really going on in an energy conversion process is greatly improved, and**
- **the knowledge, experience, creativity, and confidence (during the decision-making process) of an engineer are enhanced.**

Thank you for your attention

Appendix

Refrigeration machine for an air-condition system



Methodology for Splitting

The methodology for splitting the exergy destruction and the investment cost into endogenous/exogenous and avoidable/unavoidable parts and their combinations *is based* in this example *on thermodynamic cycles (processes)*.

The following thermodynamic cycles are needed:

The ***real cycle (process)***

The ***theoretical cycle (process)*** that corresponds to the given real cycle

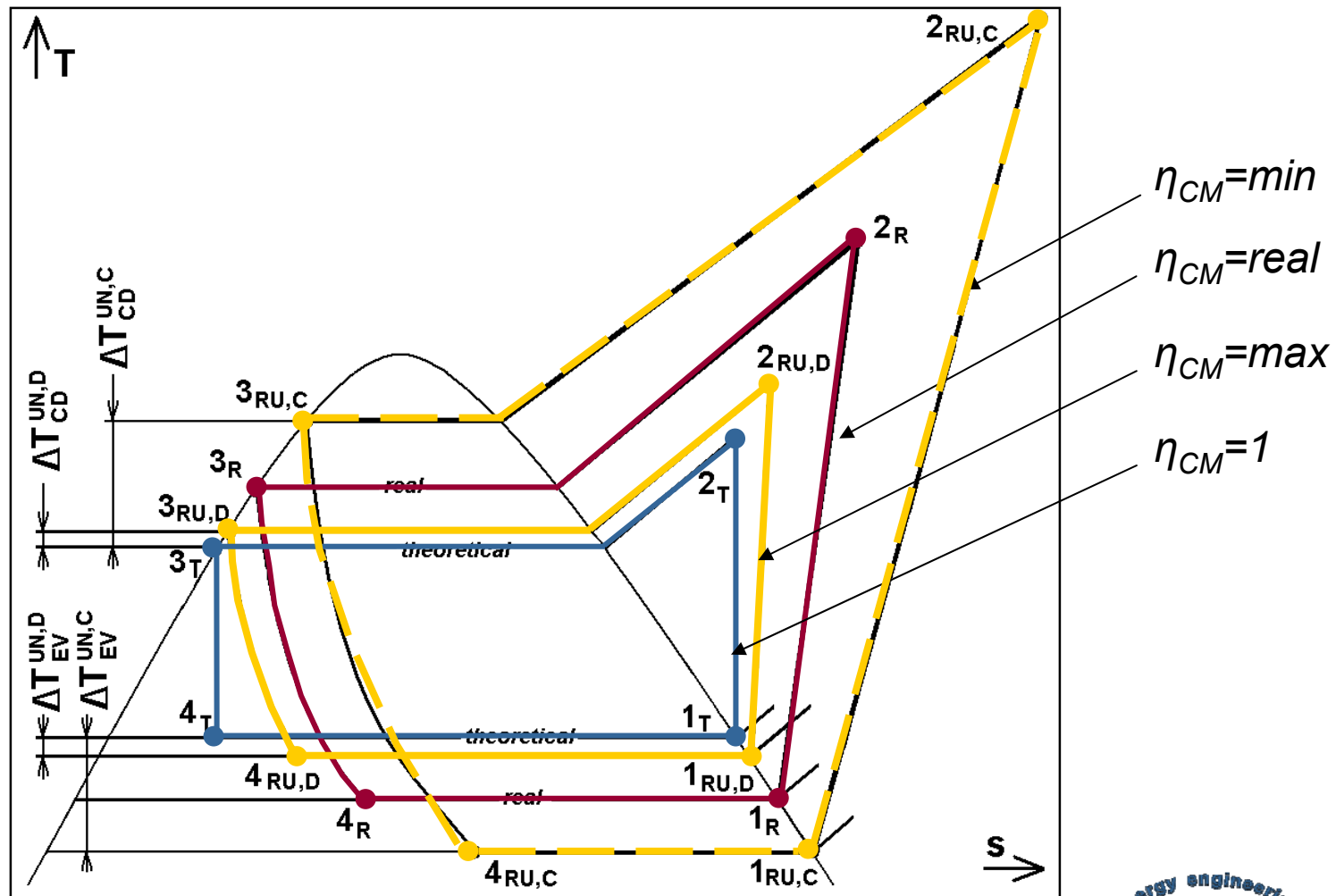
The ***cycle (process) with unavoidable exergy destruction***

The ***cycle (process) with unavoidable investment cost***

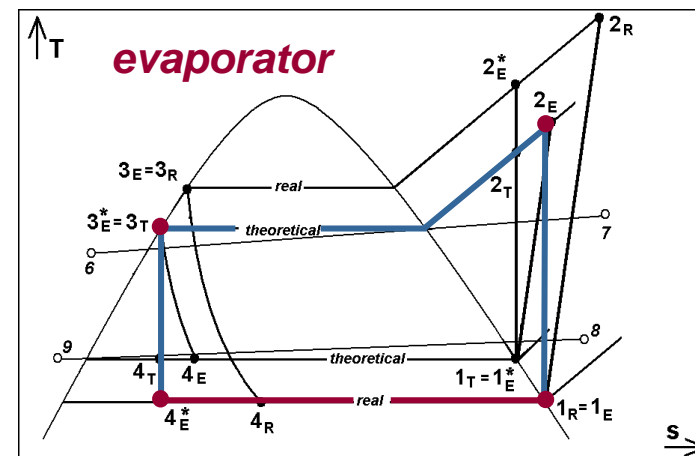
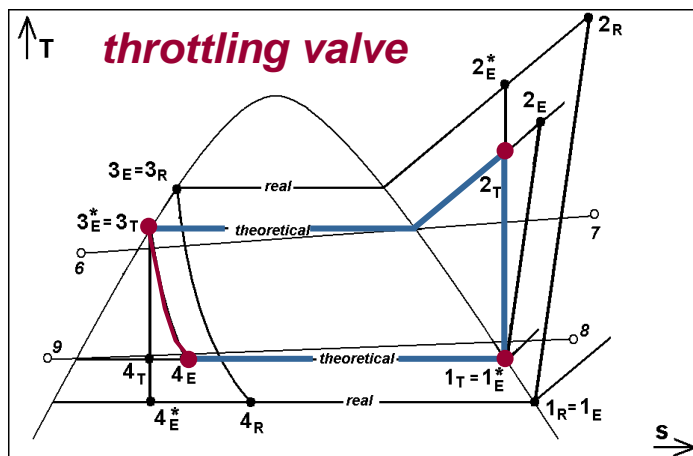
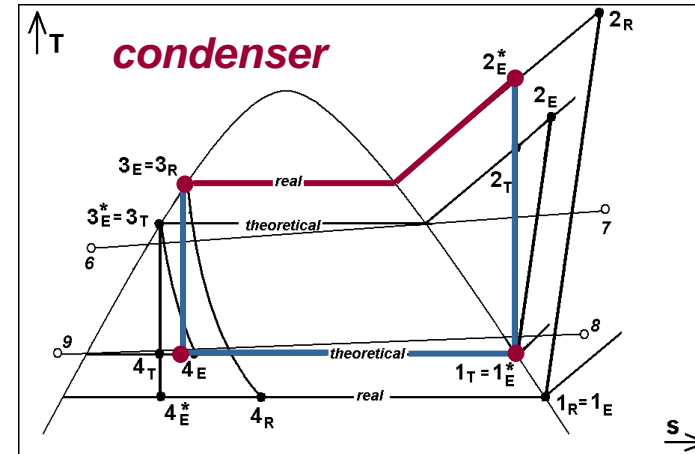
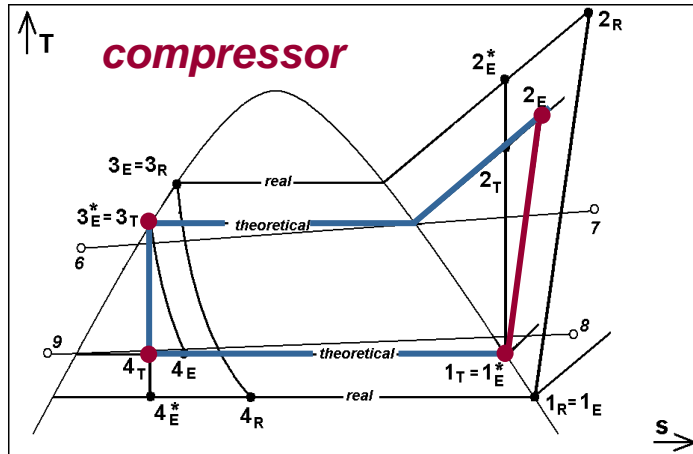
The ***hybrid cycles (processes)***.

The *hybrid cycle* contains only one process which is conducted with the same efficiency as in the *real cycle* while all other processes correspond to the theoretical cycle.

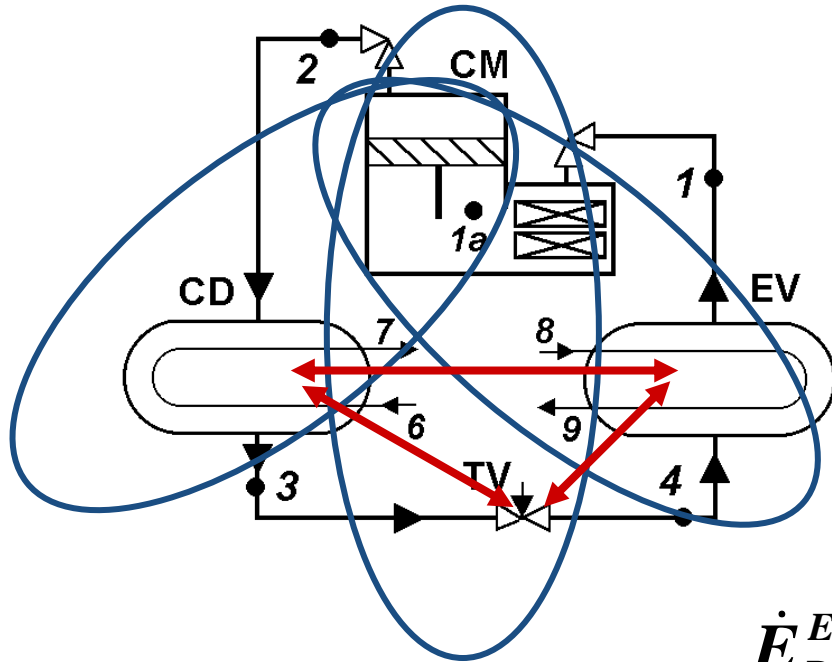
Refrigeration machine. Methodology: UN Exergy Destruction and Cost - 1



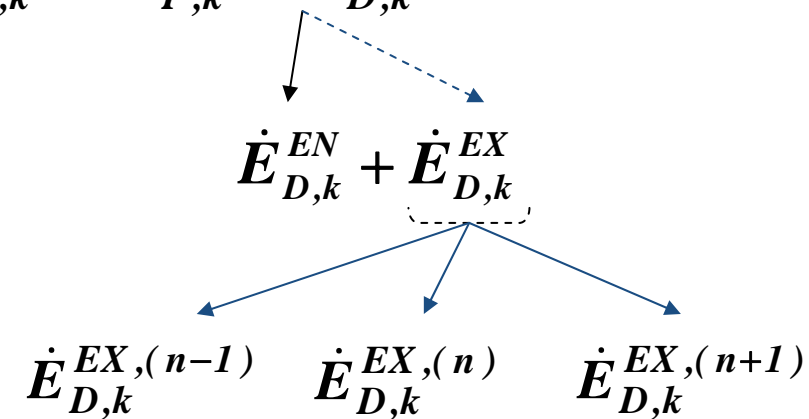
Refrigeration machine. Methodology: UN Exergy Destruction and Cost - 2



Refrigeration machine. Methodology: EX Exergy Destruction and Cost



$$\dot{E}_{F,k} = \dot{E}_{P,k} + \dot{E}_{D,k}$$



$$\dot{E}_{D,k}^{EX} > \dot{E}_{D,k}^{EX,(n-1)} + \dot{E}_{D,k}^{EX,(n)} + \dot{E}_{D,k}^{EX,(n+1)}$$

$$\dot{E}_{D,k}^{EX} = \dot{E}_{D,k}^{EX,(n-1)} + \dot{E}_{D,k}^{EX,(n)} + \dot{E}_{D,k}^{EX,(n+1)} + \boxed{\dot{E}_{D,k}^{MX}}$$

Mexogenous Exergy Destruction

Exergetic Variables: E_P and E_F

Exergy of product: \dot{E}_P

The desired result, expressed in exergy terms, achieved by the system (the k -th component) being considered.

Exergy of fuel: \dot{E}_F

The exergetic resources expended to generate the exergy of the product.

The concepts of product and fuel are used in a consistent way not only in *exergetic analyses* but also in the *exergoeconomic* and *exergoenvironmental* analyses.

Exergetic Variables: E_D and E_L

Exergy destruction: \dot{E}_D

Exergy destroyed due to irreversibilities within a system (the k -th component).

Exergy loss: \dot{E}_L

Exergy transfer to the system surroundings. This exergy transfer is not further used in the installation being considered or in another one.

Exergy balance:

$$\dot{E}_F = \dot{E}_P + \dot{E}_D (+ \dot{E}_L)$$

\dot{E}_D and \dot{E}_L are absolute measures of the thermodynamic inefficiencies.

Exergetic Variables: ε and $y_{D,k}$

Relative measures:

Exergetic efficiency: The ratio between exergy of product and exergy of fuel

$$\varepsilon_k = \frac{\dot{E}_{P,k}}{\dot{E}_{F,k}}$$

Exergy destruction ratio for the k -th component

$$y_{D,k} = \frac{\dot{E}_{D,k}}{\dot{E}_{F,tot}}$$

Exergoeconomic analysis - 2

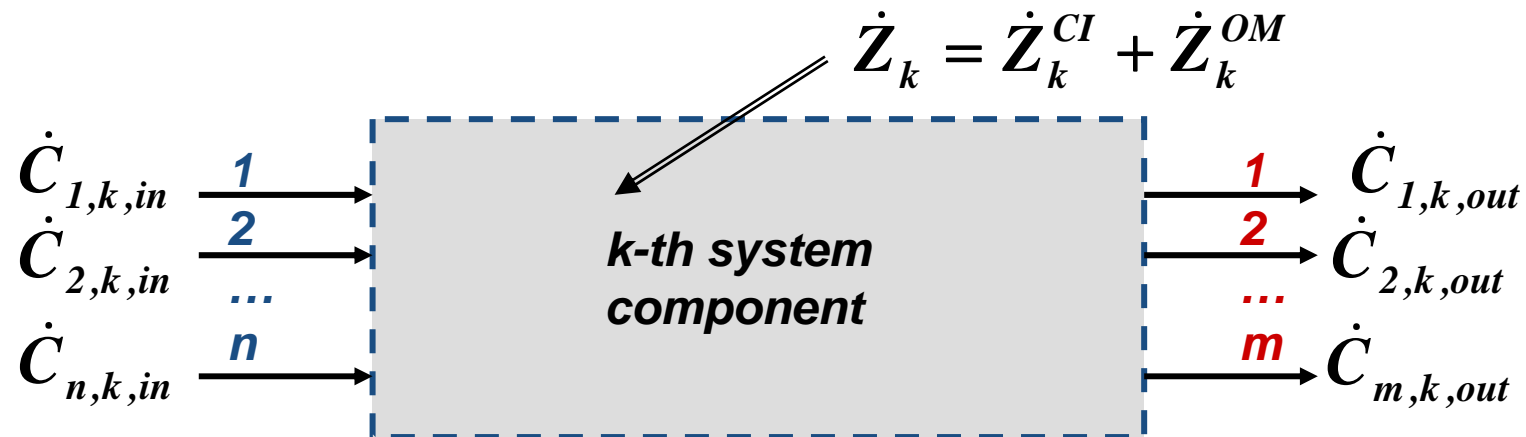
The exergy costing principle forms the basis for calculating the costs associated with each material and each energy stream in an energy conversion system.

Exergy costing

$$\dot{C}_j = c_j \dot{E}_j$$

\dot{C}_j = cost stream; \dot{E}_j = exergy stream;
 c_j = average cost per unit of exergy

Exergoeconomic analysis - 3



Cost balance applied to the *k*-th system component

$$\dot{C}_{P,k} = \dot{C}_{F,k} + \dot{Z}_k$$

$$c_{P,k} \dot{E}_{P,k} = c_{F,k} \dot{E}_{F,k} + \dot{Z}_k$$

Cost Sources

The real cost sources in an energy conversion system are:

- capital investment for each component
- operating and maintenance expenses

$$\dot{Z}_k = \dot{Z}_k^{CI} + \dot{Z}_k^{OM}$$

- cost of exergy destruction

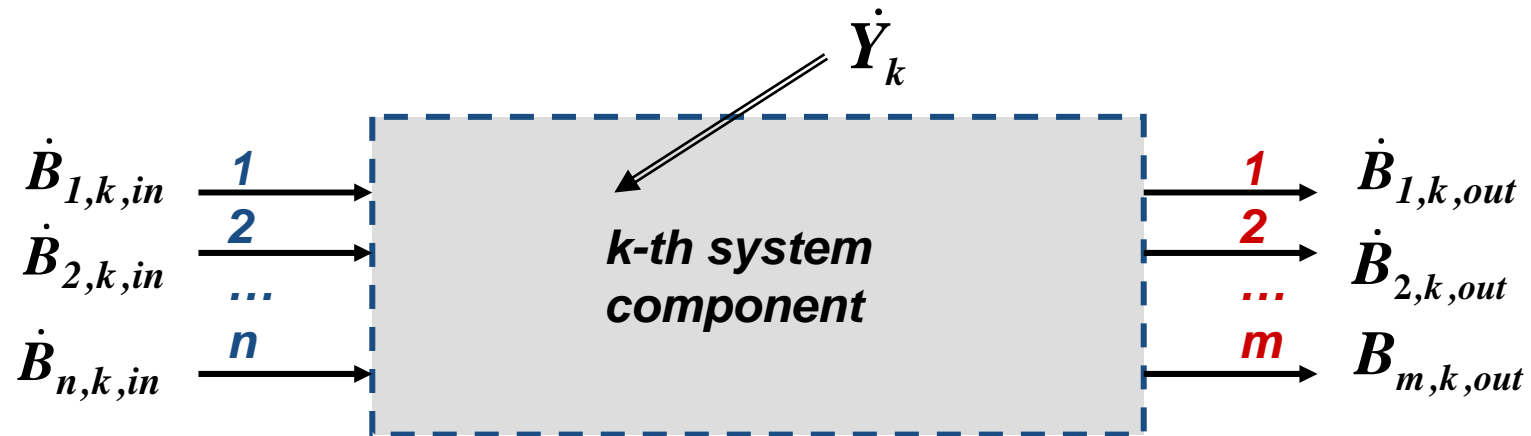
$$\dot{C}_{D,k} = c_{F,k} \dot{E}_{D,k}$$

$$\dot{C}_{D,tot} = c_{F,tot} \dot{E}_{D,tot}$$

- cost of exergy loss from the overall system

$$\dot{C}_{L,tot} = c_{F,tot} \dot{E}_{L,tot}$$

Environmental Impact Balance



$$b_{P,k} \dot{E}_{P,k} = b_{F,k} \dot{E}_{F,k} + \dot{Y}_k$$

Component-Related Environmental Impact

The *component-related environmental impact* associated with the life cycle of the k -th component is

$$\dot{Y}_k = \dot{Y}_k^{CO} + \dot{Y}_k^{OM} + \dot{Y}_k^{DI}$$

The environmental impacts that occur during the three life cycle *phases construction* (including manufacturing, transport and installation) \dot{Y}_k^{CO} , *operation and maintenance* \dot{Y}_k^{OM} , and *disposal* \dot{Y}_k^{DI} constitute the component-related environmental impact \dot{Y}_k of the k -th component.

All values of environmental impact are obtained by LCA.

Exergoeconomic Variables

Relative cost difference between the average cost per exergy unit of product and average cost per exergy unit of fuel

$$\begin{aligned} r_k &= \frac{c_{P,k} - c_{F,k}}{c_{F,k}} = \frac{c_{F,k} \dot{E}_{D,k} + \dot{Z}_k}{c_{F,k} \dot{E}_{P,k}} \\ &= \frac{1 - \varepsilon_k}{\varepsilon_k} + \frac{\dot{Z}_k}{c_{F,k} \dot{E}_{P,k}} \end{aligned}$$

Exergoeconomic factor

$$f_k = \frac{\dot{Z}_k}{\dot{Z}_k + \dot{C}_{D,k}} = \frac{\dot{Z}_k}{\dot{Z}_k + c_{F,k} \dot{E}_{D,k}}$$

Variables of the exergoenvironmental analysis

Relative difference between the average environmental impact per exergy unit of product and average environmental impact per exergy unit of fuel

$$r_{b,k} = \frac{b_{P,k} - b_{F,k}}{b_{F,k}} = \frac{b_{F,k} \dot{E}_{D,k} + \dot{Y}_k}{b_{F,k} \dot{E}_{P,k}}$$

$$= \frac{1 - \varepsilon_k}{\varepsilon_k} + \frac{\dot{Y}_k}{b_{F,k} \dot{E}_{P,k}}$$

Exergoenvironmental factor

$$f_{b,k} = \frac{\dot{Y}_k}{\dot{Y}_k + \dot{B}_{D,k}} = \frac{\dot{Y}_k}{\dot{Y}_k + b_{F,k} \dot{E}_{D,k}}$$

Definition of \dot{Z}_k^{EN} , \dot{Z}_k^{EX} , \dot{Y}_k^{EN} , and \dot{Y}_k^{EX}

Similar definitions apply also to the *endogenous* (\dot{Z}_k^{EN} , \dot{Y}_k^{EN}) and *exogenous* (\dot{Z}_k^{EX} , \dot{Y}_k^{EX}) investment cost and construction-of-component-related environmental impact

$$\dot{Z}_k = \dot{Z}_k^{EN} + \dot{Z}_k^{EX}$$

$$\dot{Y}_k = \dot{Y}_k^{EN} + \dot{Y}_k^{EX}$$

Definition of \dot{Z}_k^{UN} , \dot{Z}_k^{AV} , \dot{Y}_k^{UN} , and \dot{Y}_k^{AV}

The **unavoidable** investment cost and (\dot{Z}_k^{UN}) for a component can be calculated by assuming an extremely inefficient version of this component.

The **unavoidable** component-related environmental impact (\dot{Y}_k^{UN}) is calculated using the minimal environmental impact from each category.

To adjust for different component sizes, we calculate for each component the unavoidable cost or unavoidable construction-of-component-related environmental impact per unit of exergy of the product $\left(\dot{Z} / \dot{E}_P \right)_k^{UN}$ or $\left(\dot{Y} / \dot{E}_P \right)_k^{UN}$

New Variables for the Advanced Exergy-Based Analyses

Sum of avoidable exergy destructions caused by the component being considered

$$\dot{E}_{D,k}^{AV,\Sigma} = \dot{E}_{D,k}^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^n \dot{E}_{D,r}^{AV,EX,k}$$

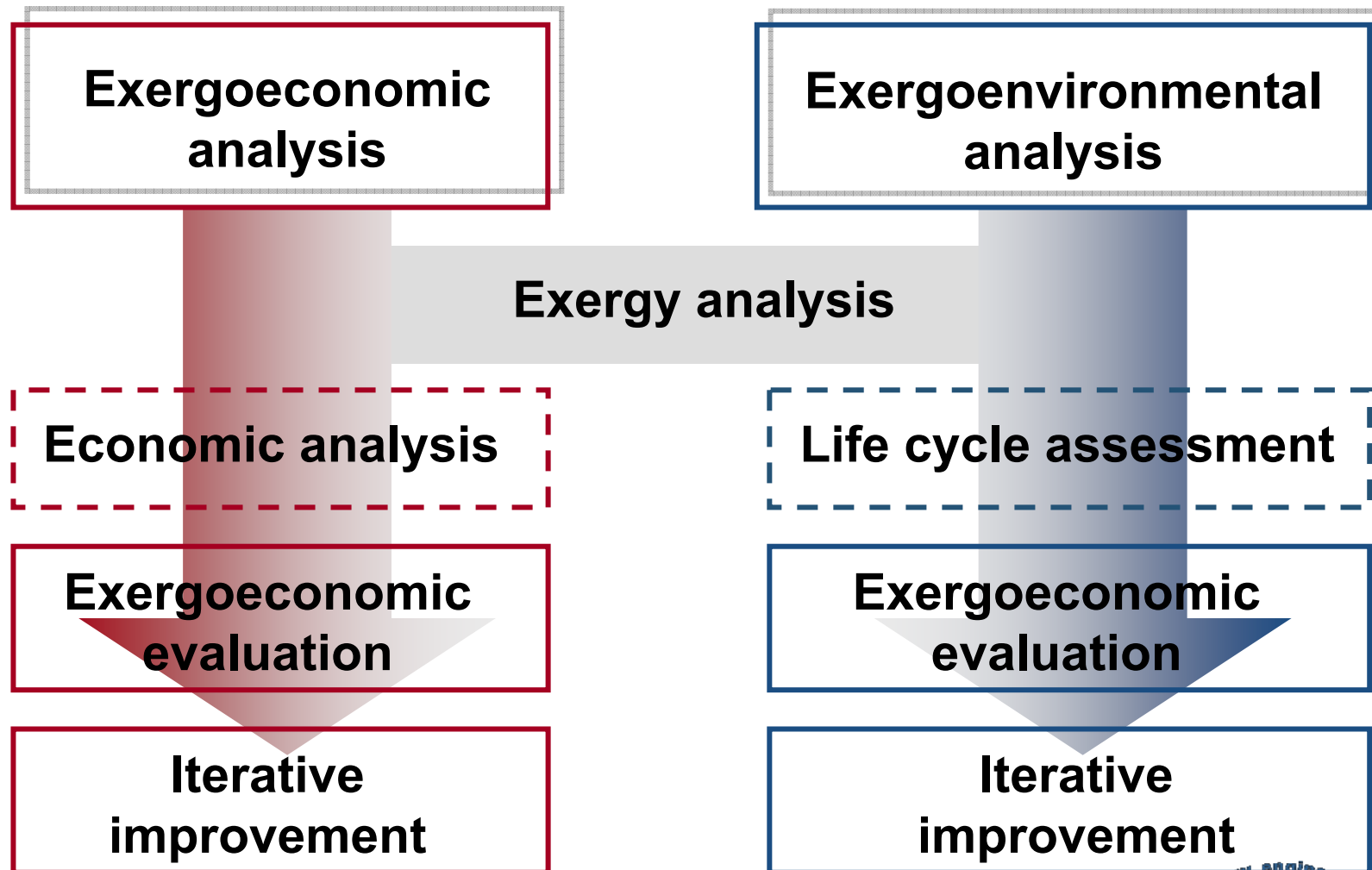
$$\dot{Z}_k^{AV,\Sigma} = \dot{Z}_k^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^n \dot{Z}_r^{AV,EX,k}$$

$$\dot{C}_{D,k}^{AV,\Sigma} = \dot{C}_{D,k}^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^n c_{F,r} \cdot \dot{C}_{D,r}^{AV,EX,k}$$

$$\dot{Y}_k^{AV,\Sigma} = \dot{Y}_k^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^n \dot{Y}_r^{AV,EX,k}$$

$$\dot{B}_{D,k}^{AV,\Sigma} = \dot{B}_{D,k}^{AV,EN} + \sum_{\substack{r=1 \\ r \neq k}}^n b_{F,r} \cdot \dot{B}_{D,r}^{AV,EX,k}$$

Exergy-Based Methods



Example: Refrigeration machine

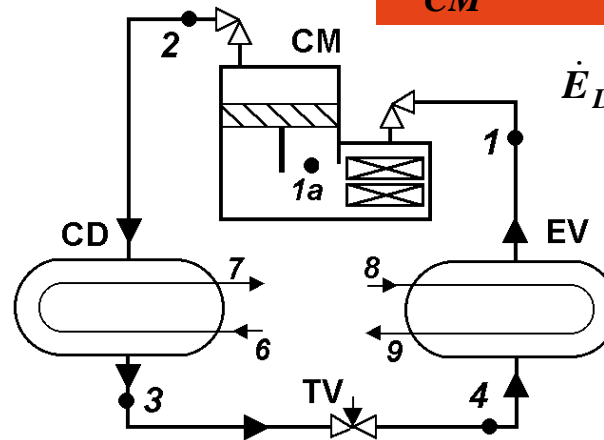
$$\dot{Y}_{CM} = 0.191 \text{ mPts} / \text{h}$$

$$\dot{Z}_{CM} = 7.90 \text{ €cent} / \text{h}$$

$$\dot{E}_{D,CD} = (\dot{E}_2 - \dot{E}_3) - (\dot{E}_7 - \dot{E}_6)$$

$$\dot{Z}_{CD} = 2.60 \text{ €cent} / \text{h}$$

$$\dot{Y}_{CD} = 0.770 \text{ mPts} / \text{h}$$



$$\dot{E}_{D,CM} = \dot{W}_{CM} - (\dot{E}_2 - \dot{E}_{1a})$$

$$\dot{E}_{D,EV} = (\dot{E}_4 - \dot{E}_1) - (\dot{E}_9 - \dot{E}_8)$$

$$\dot{Z}_{EV} = 2.70 \text{ €cent} / \text{h}$$

$$\dot{Y}_{EV} = 0.729 \text{ mPts} / \text{h}$$

$$\dot{E}_{D,TV} = (\dot{E}_3^M - \dot{E}_4^M) - (\dot{E}_4^T - \dot{E}_3^T)$$

$$\dot{Z}_{TV} = 0.1 \text{ €cent} / \text{h}$$

$$\dot{Y}_{TV} = 0.001 \text{ mPts} / \text{h}$$

Example: Refrigeration machine

Splitting the capital investment cost for components of the vapor-compression refrigeration machine

Com- ponent	\dot{Z}_k^{EN} [€ cent /h]	\dot{Z}_k^{EX} [€ cent /h]		\dot{Z}_k^{UN} [€ cent /h]	\dot{Z}_k^{AV} [€ cent /h]	Splitting \dot{Z}_k^{total} [€ cent /h]								
						\dot{Z}_k^{UN}			\dot{Z}_k^{AV}					
						$\dot{Z}_k^{UN,EN}$	$\dot{Z}_k^{UN,EX}$		$\dot{Z}_k^{AV,EN}$	$\dot{Z}_k^{AV,EX}$				
CM	7.9	6.4	CD	3.3	4.2	10.1	2.3	1.9	CD	1.0	5.6	4.5	CD	2.3
			TV	0					TV	0			TV	0
			EV	2.6					EV	0.8			EV	1.8
			mexo	0.5					mexo	0.1			mexo	0.4
CD	2.6	0.2	CM	<0.1	1.9	0.9	1.7	0.2	CM	<0.1	0.9	<0.1	CM	<0.1
			TV	<0.1					TV	<0.1			TV	<0.1
			EV	0.1					EV	<0.1			EV	<0.1
			mexo	<0.1					mexo	<0.1			mexo	<0.1
TV	0.1	0		0.1	0	0.1	0		0	0		0	0	
EV	2.7	0		0.6	2.1	0.6	0		2.1	0		0	0	

Example: Refrigeration machine

Splitting the capital investment cost for components of the vapor-compression refrigeration machine

Component	\dot{Y}_k^{EN} [mPts/h]	\dot{Y}_k^{EX} [mPts/h]		\dot{Y}_k^{UN} [mPts/h]	\dot{Y}_k^{AV} [mPts/h]	Splitting \dot{Y}_k^{real} [mPts/h]								
						\dot{Y}_k^{UN}				\dot{Y}_k^{AV}				
						$\dot{Y}_k^{UN,EN}$		$\dot{Y}_k^{UN,EX}$		$\dot{Y}_k^{AV,EN}$		$\dot{Y}_k^{AV,EX}$		
CM	0.191	0.157	CD	0.080	0.179	0.169	0.098	0.081	CD	4.1	0.093	0.076	CD	0.039
			TV	0.001					TV	0.1			TV	0
			EV	0.064					EV	3.3			EV	0.031
			mexo	0.012					mexo	0.6			mexo	0.006
CD	0.770	0.068	CM	0.014	0.110	0.728	0.101	0.009	CM	0.2	0.669	0.059	CM	0.012
			TV	0.010					TV	0.1			TV	0.009
			EV	0.036					EV	0.5			EV	0.031
			mexo	0.008					mexo	0.1			mexo	0.007
TV	0.001	0	0.001	0	0.001	0	0	0	0	0	0	0	0	
EV	0.729	0	0.131	0.598	0.131	0	0.598	0	0	0	0	0	0	