Ecopump work by Europump

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How the concepts of “House of Efficiency” and “Extended Product Approach” were developed and what they meant for Ecodesign developments

Presented at the EUROPUMP workshop

Brussels, March 7, 2013

by Prof. Dr. Bernd Stoffel

Types of pump systems

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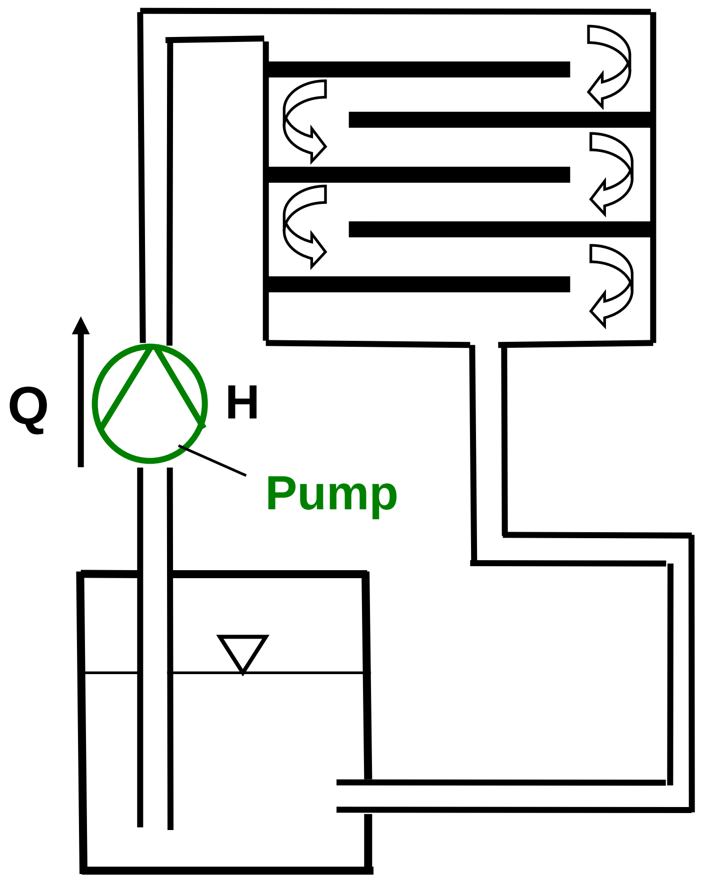
Type: closed loop



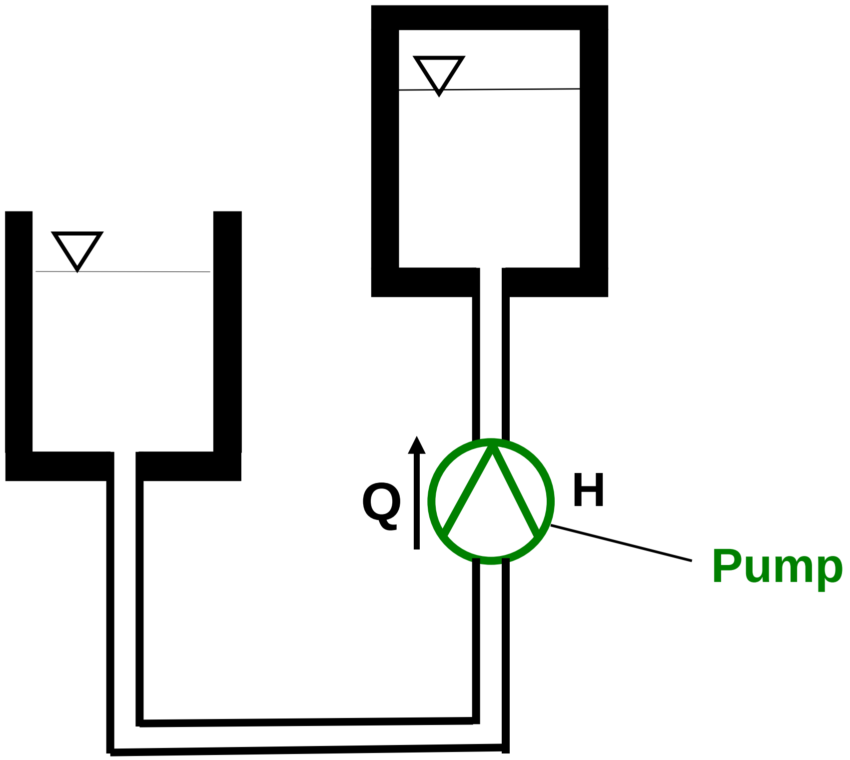
Process:
circulation of liquid

Need of the process:

- **flow rate Q ,**
- **pump head H**

Types of pump systems

Type: open loop



Process:

Transport of liquid to

- **other location,**
- **higher elevation**
- **and/or higher pressure**

⇩

Need of the process:

- **flow rate Q**
- **pump head H**

Electric power need of a pump system

Need of the process:
- flow rate Q
- pump head H

⇒ **hydraulic power output**
$P_{hyd} \sim Q \cdot H$

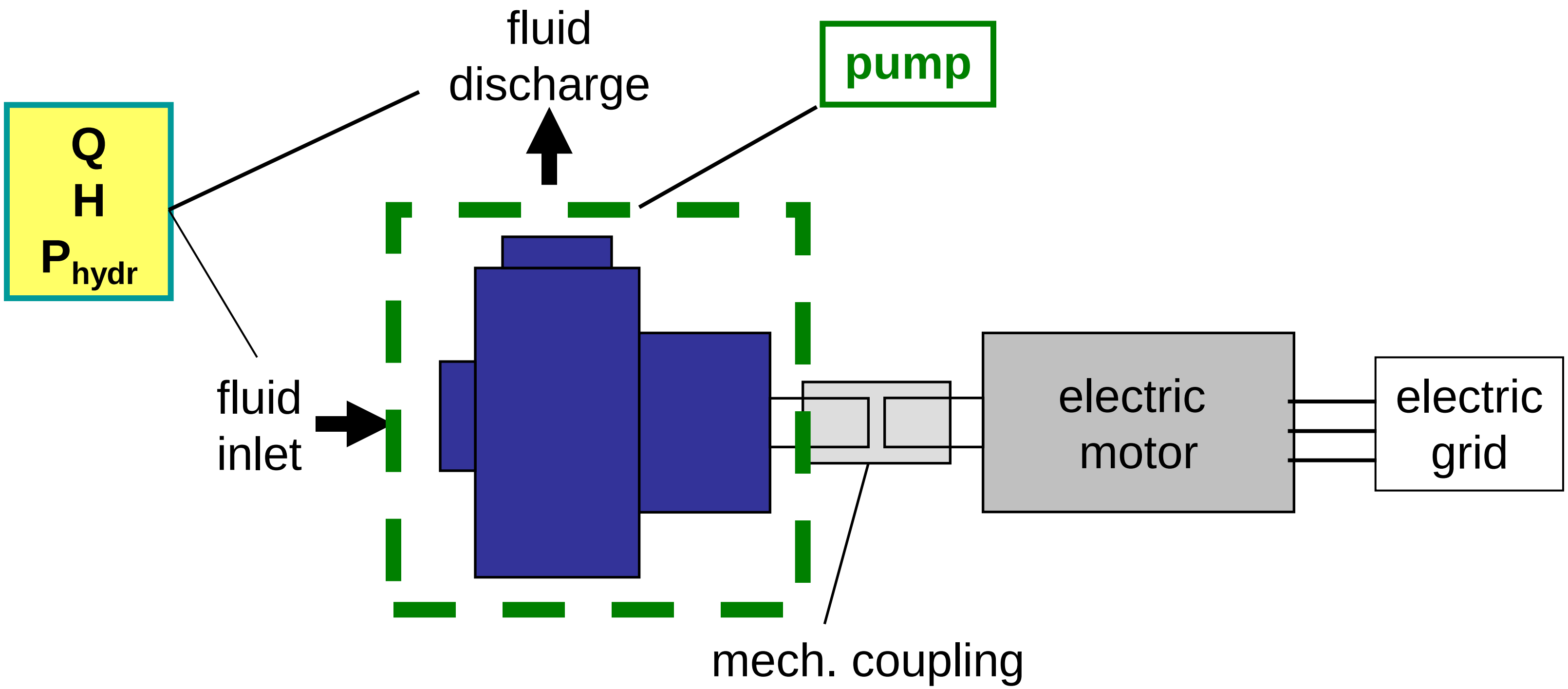
⇓

pump efficiency η_{pump} ⇒ **mechanical pump power input**
$P_{pump} \sim (Q \cdot H) / \eta_{pump}$

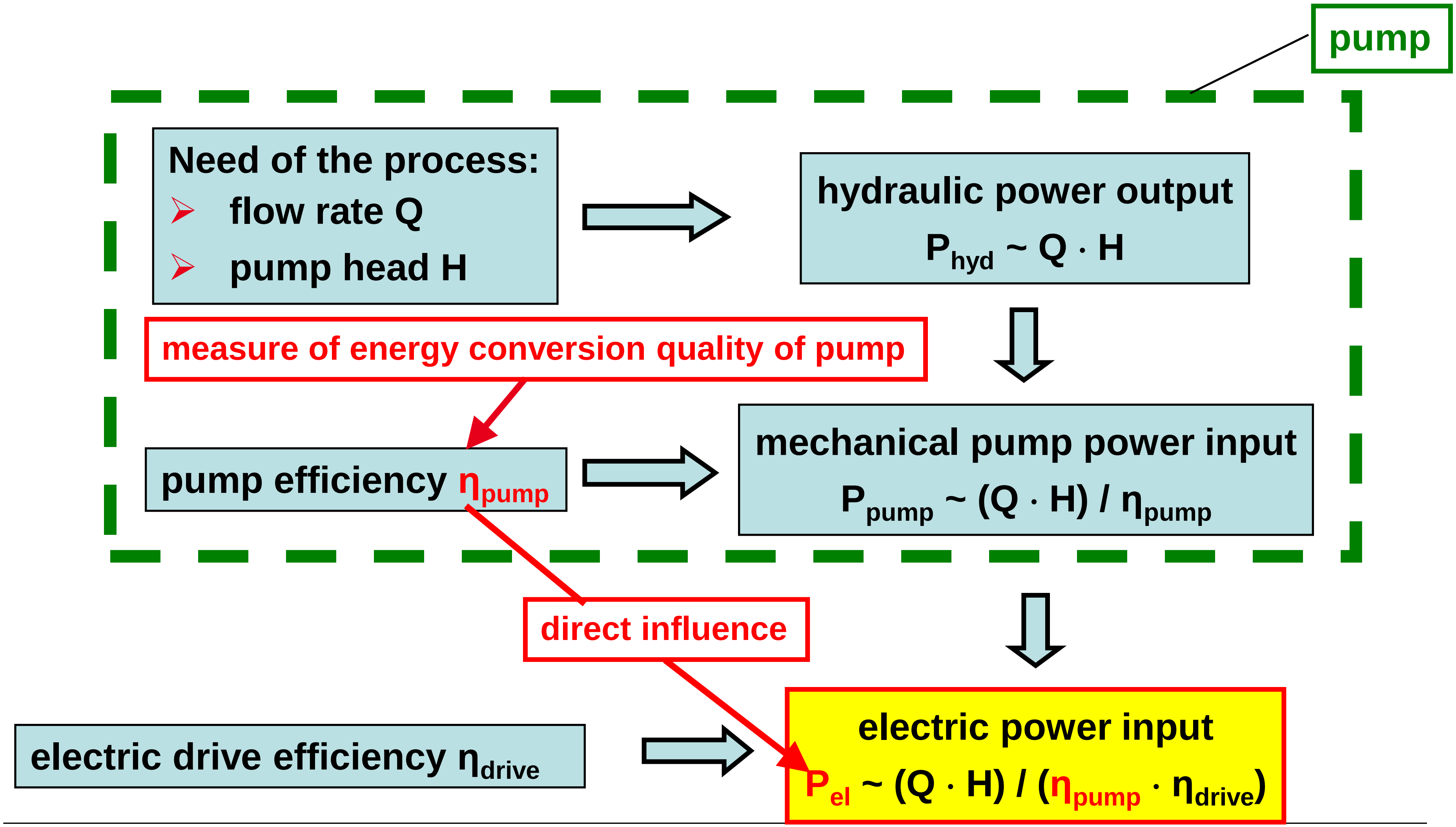
⇓

electric drive efficiency η_{drive} ⇒ **electric power input**
$P_{el} \sim (Q \cdot H) / (\eta_{pump} \cdot \eta_{drive})$

Pumps as Energy using Products (EuP´s)



Pumps as Energy using Products (EuP´s)



Focus of EUROPUMP work

EUROPUMP / Ecopump work

- **already done**
- **and presently in progress**

focuses on

- **pump types**
- **pump applications**

with

- **highest contribution to energy consumption**
- **highest potential for energy saving**

Pumps and applications in the focus of work

Kinds of **pumps** presently*) in the focus:

- circulators
- water pumps

Examples of **relevant applications**:

- Commercial buildings, drinking water supply
- Heating, ventilation, air condition (HVAC)
- Water distribution, pressure boosting in high-rise buildings
- Irrigation

***) but additional kinds of pumps (as e.g. waste water pumps) already in the focus of new EC lots**

Pumps as Energy using Products (EuP´s)

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pump

Need of the process:

- flow rate Q
- pump head H

→ **hydraulic power output**
$P_{hyd} \sim Q \cdot H$

task: fulfillment of requirements of EU regulations

pump efficiency η_{pump}

→ **mechanical pump power input**
$P_{pump} \sim (Q \cdot H) / \eta_{pump}$

aim: reduction of energy consumption and CO_2 emission

electric drive efficiency η_{drive}

→ **electric power input**
$P_{el} \sim (Q \cdot H) / (\eta_{pump} \cdot \eta_{drive})$

FLUID SYSTEM TECHNIK

Approach: „House of Efficiency“

Background:

- in many processes, pumps are operated not only at (or very near to) their BEP, but in a range of Q/Q_{BEP}
- this applies to closed and open loops

Consequence:

- energy efficiency of operation is determined not only by η_{BEP}, but also by pump efficiency at part load ($Q < Q_{BEP}$) and overload ($Q > Q_{BEP}$)
- assessment of pump quality regarding energy efficiency should be based on pump efficiency at 3 values of Q/Q_{BEP}

so-called „House of Efficiency“

Requirements on pump efficiency

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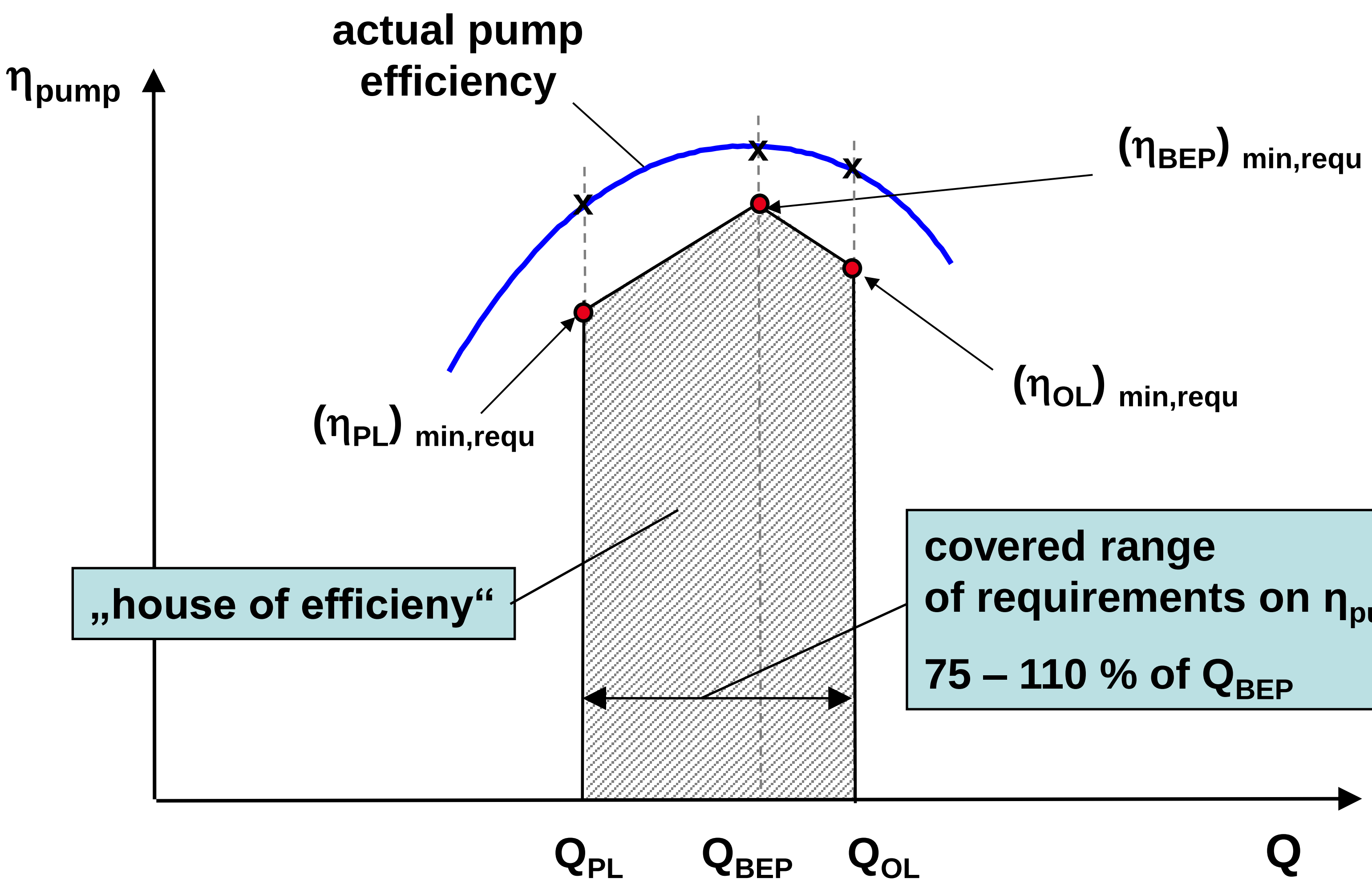

FLUID SYSTEM TECHNIK

Minimum required pump efficiency

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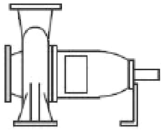
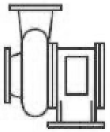
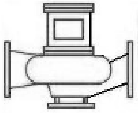
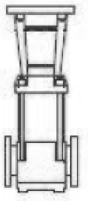
Values of minimum required pump efficiency

- **were elaborated by a study at TU Darmstadt**
- **are based**
  - **on statistical evaluations of data of nearly 2.400 „state of the art“ pumps of European manufacturers, collected by questionnaires**
  - **and on general fluiddynamic laws and technological aspects**

Pump types included in the evaluation

ESOB End Suction Own Bearings pump	
ESCC End Suction Close Coupled pump	
ESCCI Inline End Suction Close Coupled pump	
MS Multistage pump	
MSS Submersible Multistage pump	

Minimum required pump efficiency

Results of EUROPUMP study carried out at Darmstadt University

$$n_s = n_N \cdot \frac{Q_{BEP}^{0.5}}{60 \cdot \left(H_{BEP}/i\right)^{0.75}}$$

$x = \ln(n_s)$

$$(\eta_{BEP})_{min,requ} = -11.48\,x^2 - 0.85\,y^2 - 0.38\,x\,y + 88.59\,x + 13.46\,y - C$$

$y = \ln(Q_{BEP})$

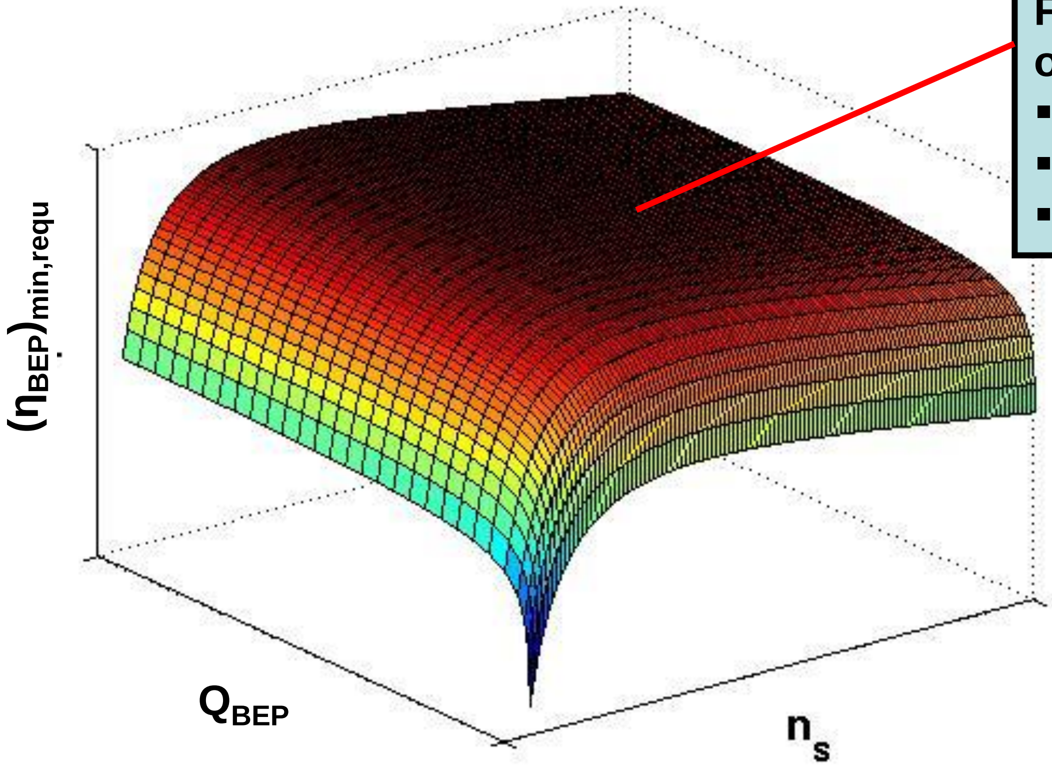
units:

η	in %
Q_{BEP}	in m³/h
H_{BEP}	in m
n_N, n_s	in 1/min
i:	number of stages

C depends on
- pump type
- nominal speed n_N
- Minimum Efficiency Index (MEI)

Minimum required pump efficiency

Results of EUROPUMP study carried out at Darmstadt University



Functional dependence of $(\eta_{BEP})_{min,requ}$ for

- **a pump type**
- **a nominal speed**
- **a value of MEI**

Minimum Efficiency Index (MEI)

MEI

- **is a decimal number < 1.0**
- **serves for EU regulation on water pumps**
- **has a competitive effect on the market**
- **quantifies the „cut-off effect“**

Table of C-values

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Minimum efficiency index (MEI) and its corresponding C-value depending on the pump type and speed

C-value for MEI / $C_{PumpType, rpm}$	MEI = 0,10	MEI = 0,20	MEI = 0,30	MEI = 0,40	MEI = 0,50	MEI = 0,60	MEI = 0,70
C (ESOB, 1 450)	132,58	130,68	129,35	128,07	126,97	126,10	124,85
C (ESOB, 2 900)	135,60	133,43	131,61	130,27	129,18	128,12	127,06
C (ESCC, 1 450)	132,74	131,20	129,77	128,46	127,38	126,57	125,46
C (ESCC, 2 900)	135,93	133,82	132,23	130,77	129,86	128,80	127,75
C (ESCCI, 1 450)	136,67	134,60	133,44	132,30	131,00	130,32	128,98
C (ESCCI, 2 900)	139,45	136,53	134,91	133,69	132,65	131,34	129,83
C (MS-V, 2 900)	138,19	135,41	134,89	133,95	133,43	131,87	130,37
C (MSS, 2 900)	134,31	132,43	130,94	128,79	127,27	125,22	123,84

Minimum required pump efficiency

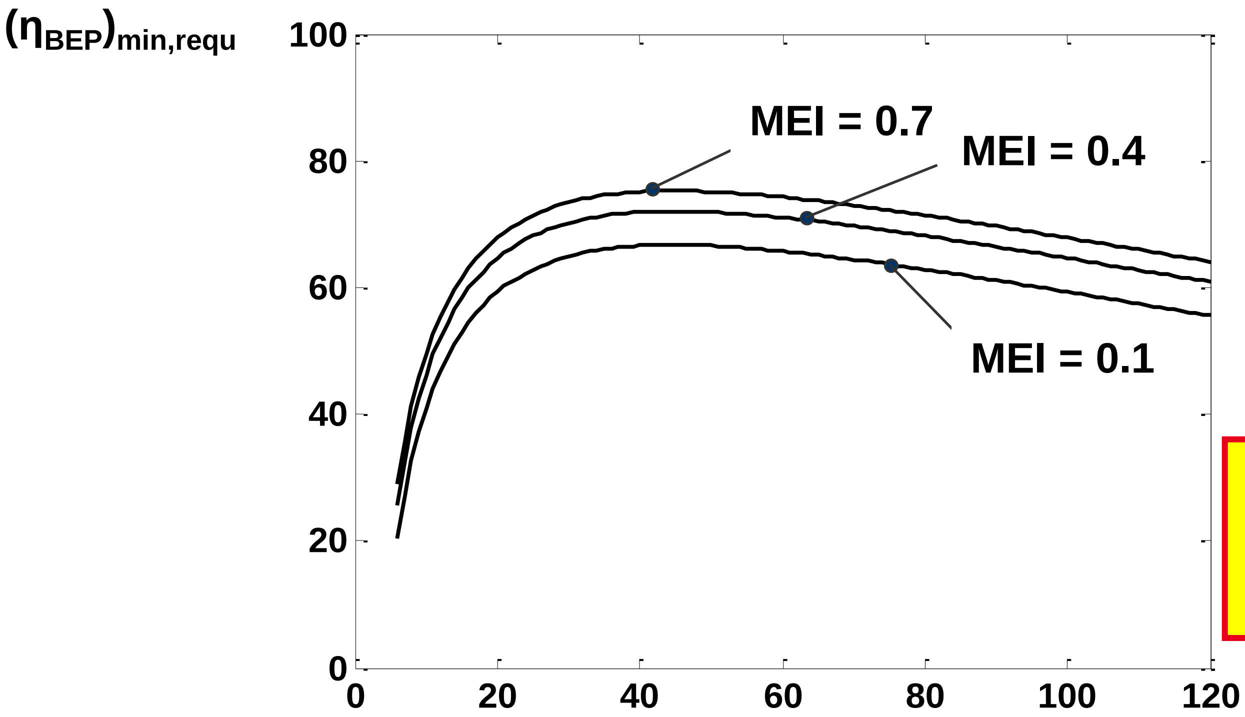


Diagram valid for:

pump type ESOB

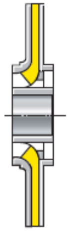
n_N = 2900 1/min

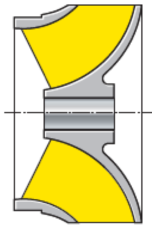
Q_{BEP} = 32 m^3/h

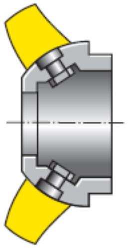
MEI = 0.1→ MEI = 0.4:

Δη ≈ 5 %

corresponding Impeller shape:







Minimum required pump efficiency

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Example :

type ESOB, n_N = 2900 min^{-1}

Q_{BEP} = 96 m^3/h , H_{BEP} = 25 m

$\Rightarrow$ n_s = 42.4 1/min

MEI	**0.1**	**0.4**	**0.7**
$(\eta_{BEP})_{min,requ}$ [%]	**72.4**	**77.7**	**80.9**

Minimum required pump efficiency

Further result fom statistical evaluation

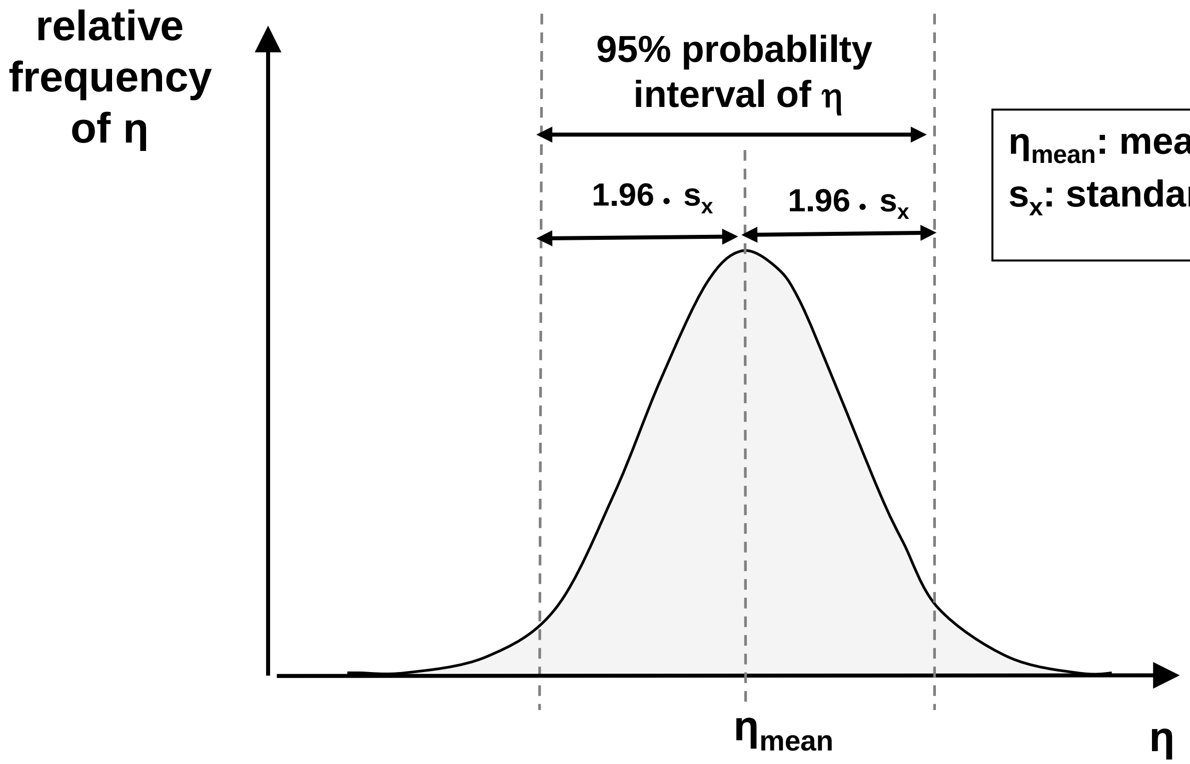
Minimum required efficiency at part load ($Q = 0.75\ Q_{BEP}$)

$$\left(\eta_{PL}\right)_{min,\ requ} = 0.947 \cdot \left(\eta_{BEP}\right)_{min,\ requ}$$

Minimum required efficiency at overload ($Q = 1.1\ Q_{BEP}$)

$$\left(\eta_{OL}\right)_{min,\ requ} = 0.985 \cdot \left(\eta_{BEP}\right)_{min,requ}$$

Statistical distribution of pump efficiency within a pump size resulting from manufacturing tolerances



η_{mean}: mean value of η

s_x: standard deviation of η

Tested pumps are samples of the corresponding size, uncertainty of η_{mean} decreases with increasing number of tested pumps

Legislation and standardisation on energy efficiency of water pumps

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EUROPUMP

Joint Working Group EuP/ErP:

- **Study on state-of-the-art**
- **Elaboration of draft standard**

European Commission

- **Preparatory study on energy consumption and potential of energy saving**
- **Regulation 547/2012 „Implementing Directive 2009/125/EC …with regard to ecodesign requirements for water pumps"** (came into force 01/01/2013)
- **Transitory document C 402/17** published 29/12/2012 (describes verification procedure, will be replaced by EN 16480)

CEN TC 197

- **EN 16480: „Pumps - Minimum required efficiency of rotodynamic water pumps"** 2nd version currently prepared for voting, publication expected still in 2013

Accordance of EU regulation 547/2012 and Standard EN 16480

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Full accordance exists in respect to

- **scope**
- **definition and application of MEI as a measure for energy efficiency of pumps**
- **methodology to verify conformity by market surveillance**

Additional items of EU Regulation

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EU regulation 547/2012

- **sets minimum values of MEI to be fulfilled for conformity**
  - **1st step: MEI_{min} = 0.1**
  - **2nd step: MEI_{min} = 0.4**
- **fixes dates for MEI_{min}-values to become mandatory**
  - **1st step: 01/01/2013**
  - **2nd step: 01/01/2015**
- **gives as a benchmark value MEI = 0.7**
- **describes product information requirements (nameplate, documents)**

Additional items of EN Standard

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EN 16480

- **explains MEI and its background**
- **recommends and describes methods to qualify pump sizes for conformity with EU regulation (by the manufacturer)**
- **gives information on**
  - **performing tests and evaluating test data in respect to MEI**
  - **tolerances**

Qualification of a pump size for MEI by the pump manufacturer

Two possibilities provided in EU Regulation and in EN Standard

- **Indication of conformity (EC sign) by proving that $MEI_{mean} \geq MEI_{min,requ}$**
- **Indication of MEI_{mean} as numerical value with 2 digits (e.g. MEI ≥ 0.35)**

Qualification of a pump size for MEI by the pump manufacturer

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Steps to do by the manufacturer:

1. **Performing tests and evaluations on sample pumps as described in EN Standard**
2. **determining the „worst" of the 3 η-values (PL, BEP, OL) in respect to MEI**
3. **calculation of MEI_{mean} by linear interpolation between C-values given in the table and**
4. **taking account of effects of measurement uncertainties and manufacturering tolerances on MEI_{mean}**
5. **check if MEI_{mean} fulfils requirement by law**
6. **indicating fulfillment or numerical value**

Verification of MEI by market surveillance

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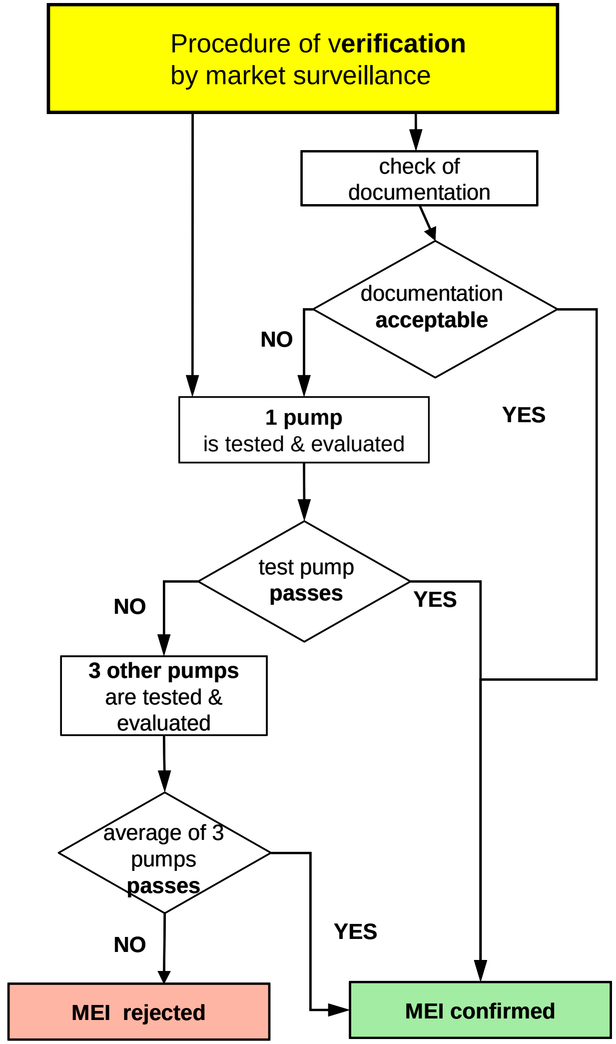
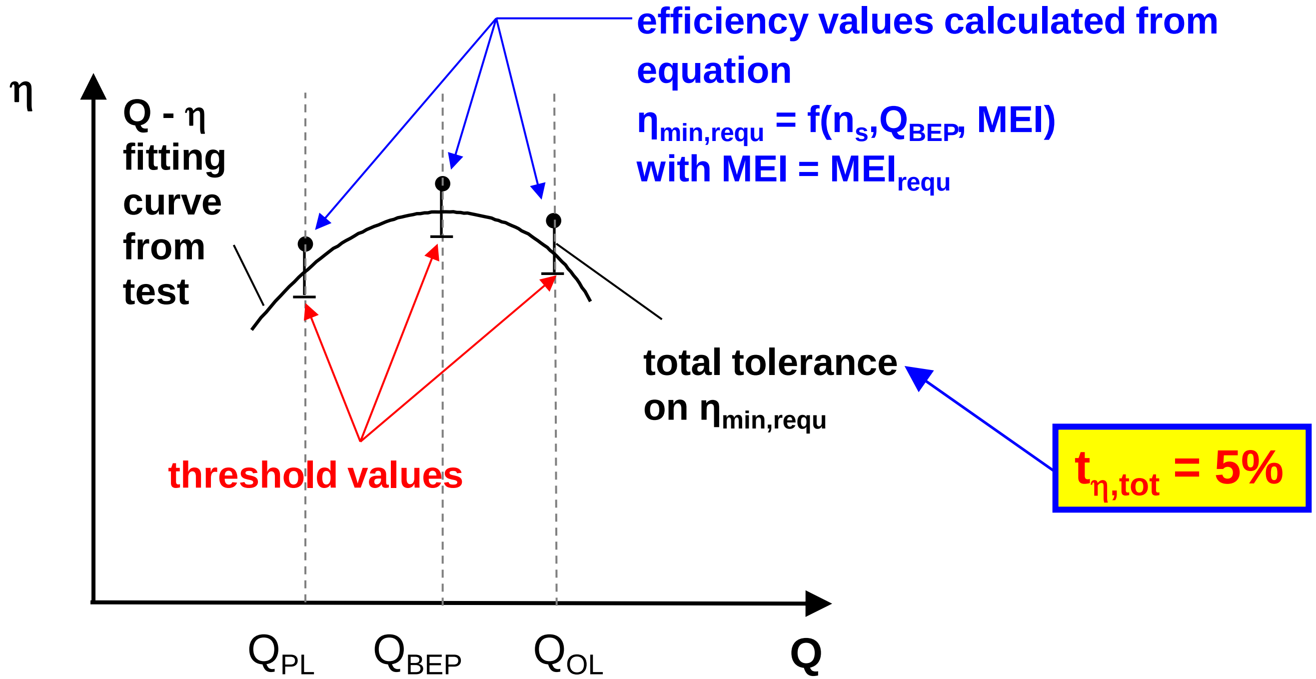


Verification of MEI by market surveillance



⇒ threshold values for verification = 0.95 ·(values calculated for relevant MEI)

Typical features of relevant applications

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For many applications in the focus

- **at most part of operating time, the needed flow rate is < $Q_{100\%}$**
- **the head $H_{process}$ needed by the process decreases with decreasing flow rate Q**
- **representative „load profiles“ or „duty profiles“ (= time fractions at $Q/Q_{100\%}$) can be defined**
- **also representative „control curves“ $H_{process}$ = f(Q) can be defined**

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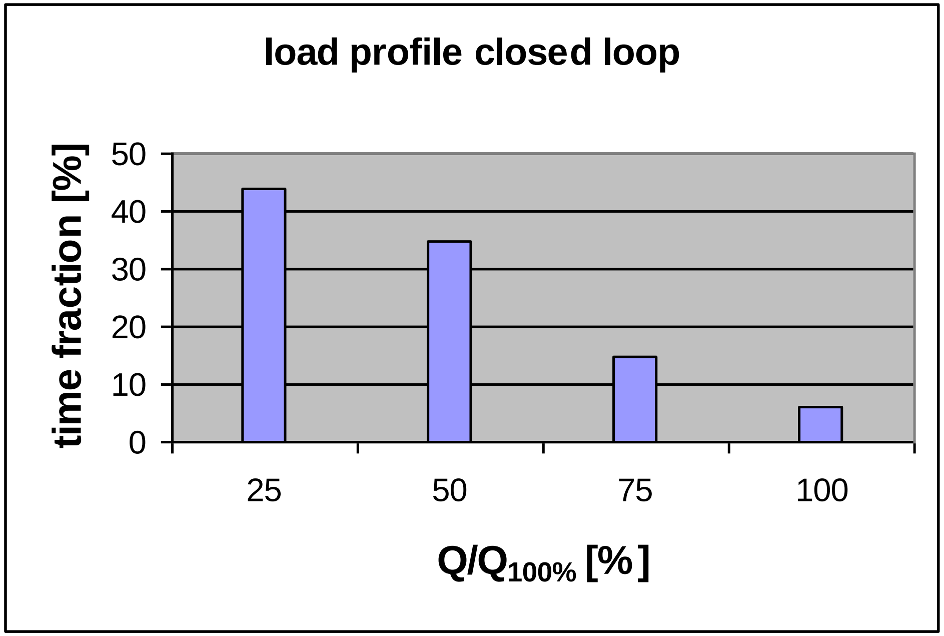
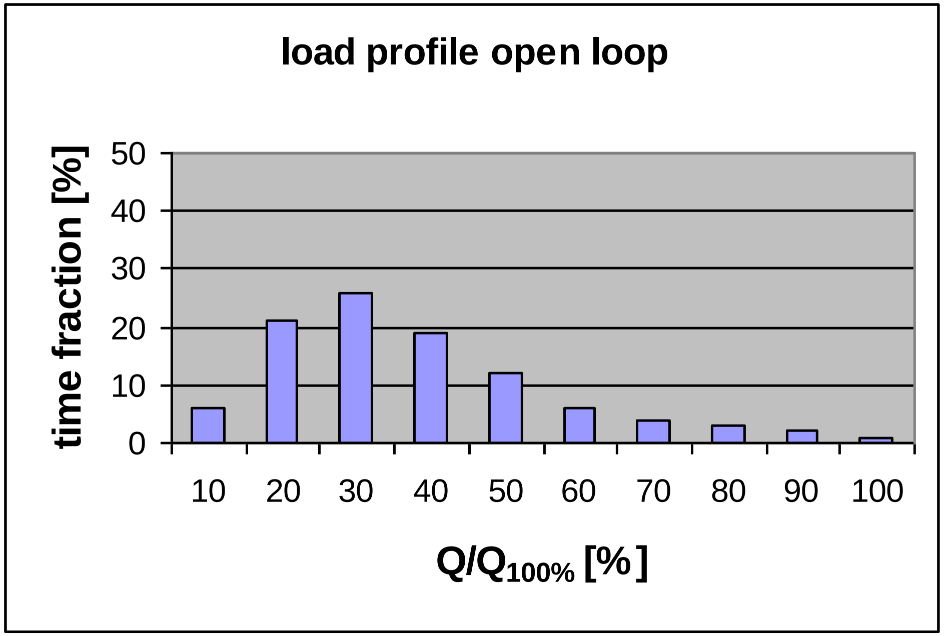
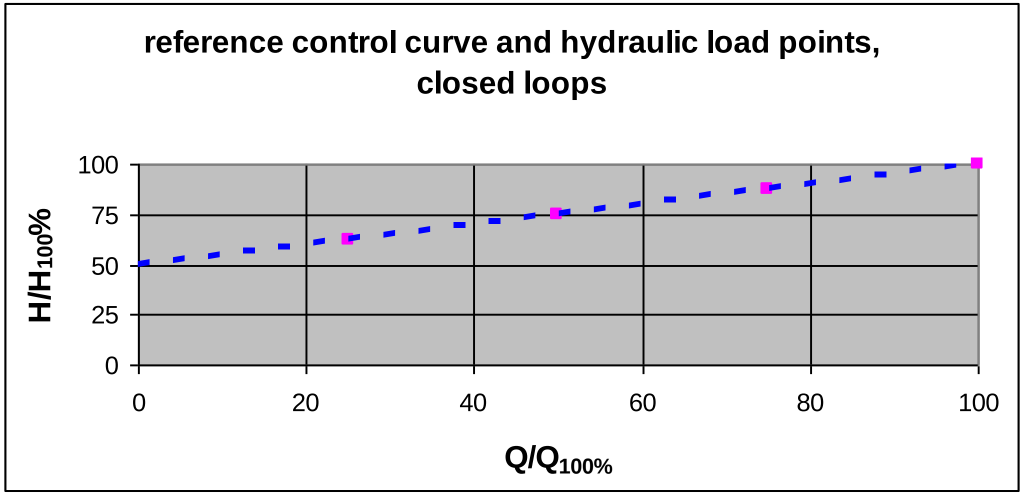
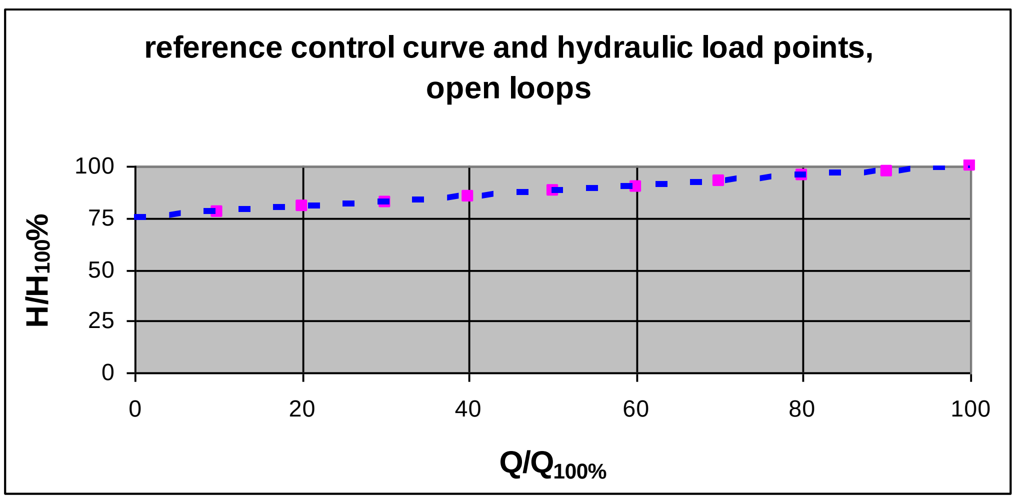
Reference load (duty) profiles





Reference control curves





reference control curves

hydraulic load points

Extended product approach

Energy efficiency of pump units (= pump + motor system) can be better assessed by the Energy Efficiency Index (EEI) *)

Definition of EEI:

$$EEI = \frac{P_{el,avg}}{P_{el,ref}}$$

with:

$$P_{el,avg} = \sum_{i=1}^{i=N} \left[\left(\frac{\Delta t}{t_{tot}} \right) \cdot P_{el,i} \right]$$

Extended Product Approach (EPA)

*) **EEI is already established in EN-Standardization and EU-Regulation for circulators**

Extended product approach

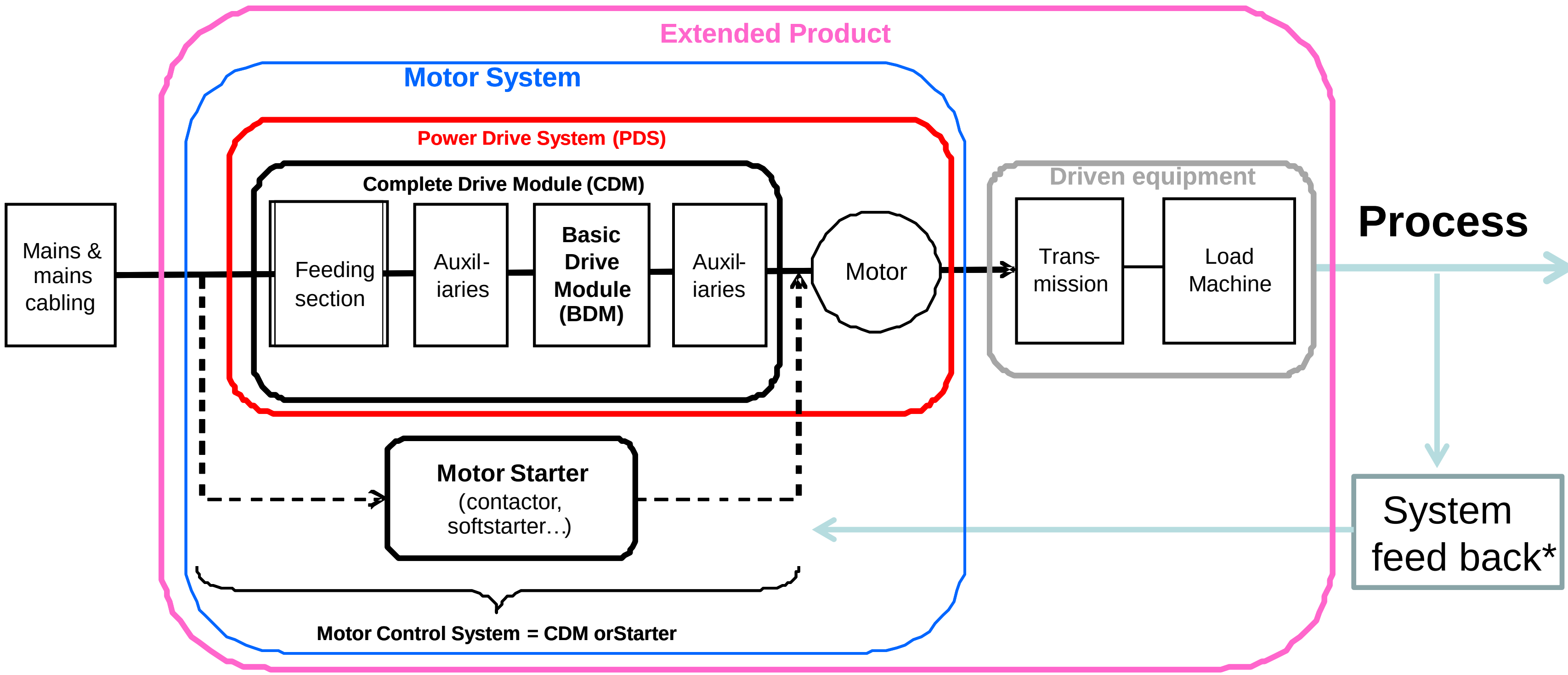
Definition of pump units as Extended Product (according to EUROPUMP and CENELEC):

- **A pump unit as an Extended Product (EP) consists of a pump driven by an electric motor system**
- **A motor system is an electric motor with or without a CDM (Complete Drive Module)**
- **A PDS is a motor system with a CDM (Complete Drive Module) for variable speed operation**

EuP/ErP – Extended Product Approach (EPA)

Example for Extended Product:

Source: CENELEC PDS Standard, page 3



The Extended Product Approach needs additionally a duty profile and a control curve.

Extended Product Approach (EPA)

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Pump unit = Extended Product

Need of the process:
- flow rate Q
- pump head H

⇒

hydraulic power
$P_{hyd} \sim Q \cdot H$

⇓

pump efficiency η_{pump}

⇒

mechanical pump power input
$P_{pump} \sim (Q \cdot H) / \eta_{pump}$

aim: reduction of energy consumption and CO_2 emission

⇓

motor system efficiency η_{drive}

⇒

electric power input
$P_{el} \sim (Q \cdot H) / (\eta_{pump} \cdot \eta_{drive})$

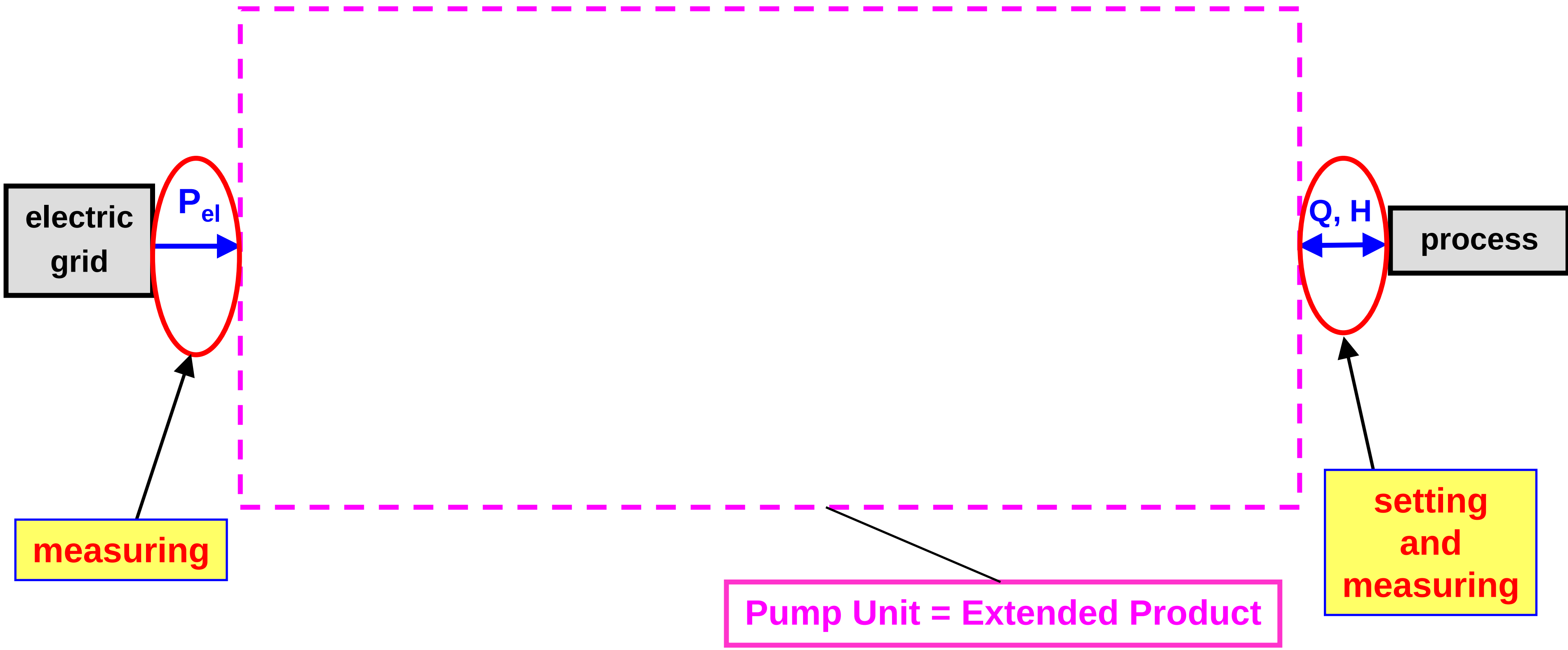
Energy Efficiency Index (EEI)

Project of EUROPUMP Joint Working Group EuP/ErP with TU Darmstadt on development and validation of EEI methodology for pump units

- **started Jan. 2011**
- **shall be finished end of 2013 with Draft Standard for EEI of EP´s**

Methods to determine EEI of pump units

1st method: Setting the defined load points and measuring corresponding P_{el}



Methods to determine EEI of pump units

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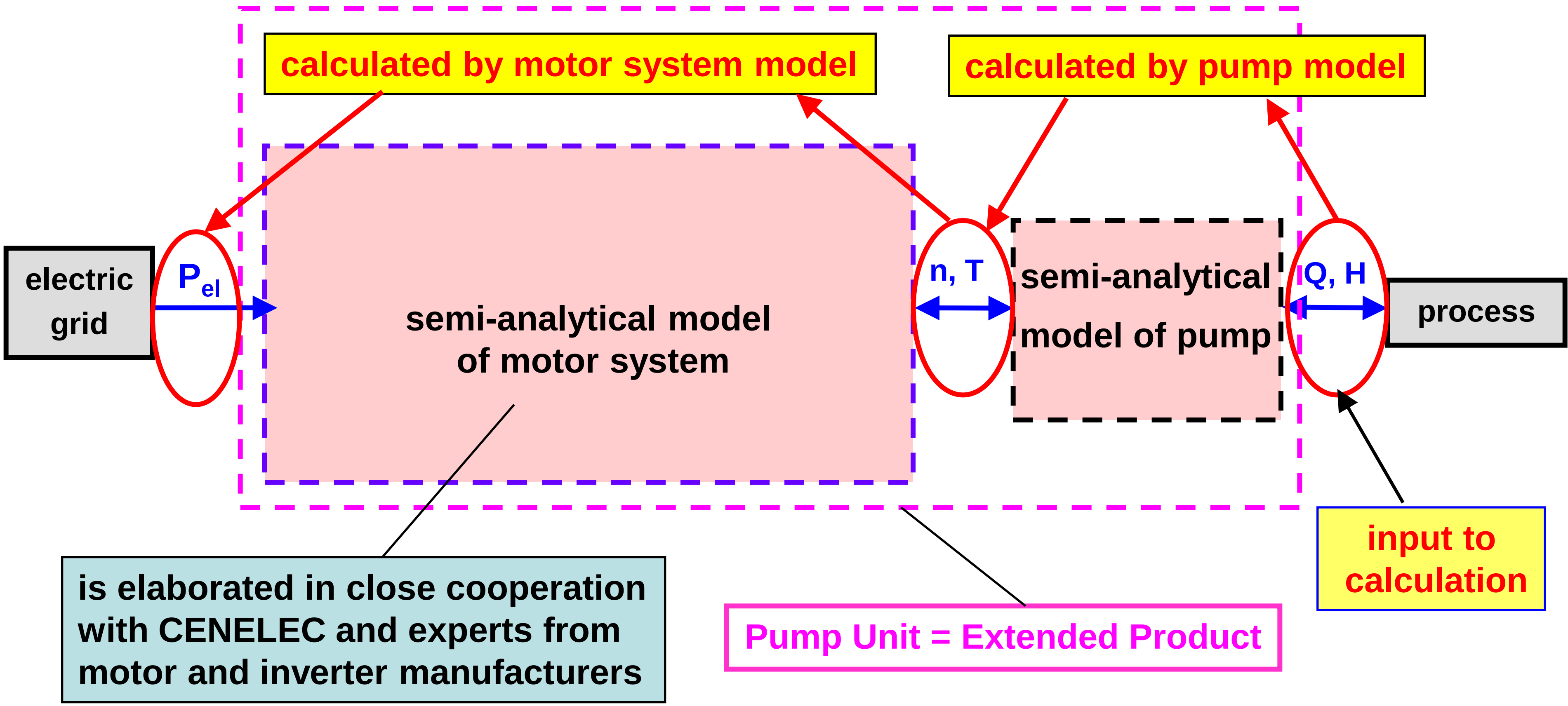
2nd method: Calculating P_{el} by using semi-analytical models



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Thank you for your attention