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Development and Education



EMEE - Lecture n. 08

Energy indicators

„The purpose of comparing each other is to find out our position to others. Of course, it depends on the parameter according to which we compare - the comparison indicator. This parameter can vary considerably, which is certainly a subjective matter. But in production systems, it's the same as in sports - we just want to be the first in a competition where everyone does the same thing.“

e.d.

2

Lecture content

1) What is the criterion for comparing individual energy systems with each other.
2) Where in the system the comparison is made.
3) How to determine the material production realized by the consumed work.
4) Calculation of ES indicators.

3

Subject Comparison = Competition of ES

The winner is not the one who has the most but the one who best meets the conditions of the competition.



- Objective function of energy system:
  - to satisfied consumers request for the amount of the work.
  - consumers is used work for realisation of:
    - their business activities (production) or services for customers – non residential use,
    - use work for personal use – residential use.
- The amount of the work is the absolute value that they need in the scope of period T, which is Load Diagram.
  - The total consumed value is not criterion of the competition but it only represents what value the competitors has to the disposal.
- The objective criterion which only can guarantee victory is how effectively we uses our work.

4

Why is necessary make energy balances?

To make the power balances of the power systems is the base off all. We are already able to determine total (absolute) value of the primary sources (balance sources) and finally sources and consumption of them by consumers:

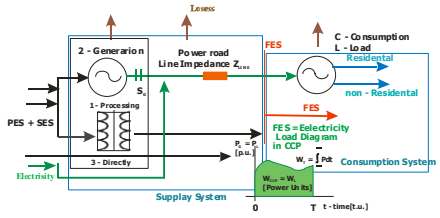
- The power balance is necessary to make up in regular interval. There are very useful not only for the power system but for every systems or equipment which use power for their activity.
- We can say that without the power utilization is nothing – no life, no movement, no production.
- In power balances in power systems we are making the screening of energy equipments, eventually, the screening of the power subsystems, or the whole power economy.
- The power balance of single territory of the whole area (state, continent and world) is useful for us.
- We can determine the power losses reason. The present state of power equipment, state after reconstruction should be ensuring.

5

Objective function of ES with EES subsystem

ES – Energy System for power satisfaction of energy appliances in the system:

- It generates, transform or directly deliver Finally Energy Sources consumed by appliances from Primary Energy Sources (Secondary Energy Sources).
- EES subsystem for electricity consumption – presented by green line.



6

Territory power balance

To manage any state region county, region to family it is necessary to make balances and look for ways to meet demand. Nothing can be control without real knowledge of the state.

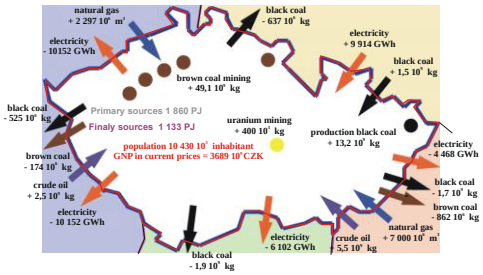
- The territory power balance can be:
  - resultant – for privies period,
  - forecast balance – for determined future period.
- The goal of the resultant balance is:
  - to determine state of the up to now power industry of the definite territory – state,
  - to draw attention in power supplying,
  - to identify source materials for forecast balance.
- The goal of the territory power balance is:
  - to ensure the necessary power amount in necessary structure,
  - to ensure development of the technical and economy progress in power industry.
- The basic principle of power balance we know - energy conservation law. The balance we separate to two basic parts:
  - on production side
  - on consumption side

7

Territorial representation of the ES objective function

Determination total work of the system for period of T=1 year of LD_T absolute values in CZ:

- Inputting energy flows have + notification.
- Circles are home energy sources.
- GDP – value of material product on the given territory.



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Tabular determination of ES objective function - 1

The territory power balance – transformation PEZ to FES of Czech Republic (ES) in 2008:

Balance Item	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro	Geothermal Solar etc.	Combustible Renewables & Waste	Electricity	Heat	Total
Production	**953,97**	**12,91**	-	**6,72**	**290,67**	**7,29**	**1,13**	**100,48**	-	**1,11**	**1 374,28**
Imports	86,87	345,01	113,69	327,12	-	-	-	4,22	30,68	-	907,58
Exports	-214,27	-0,85	-55,12	-33,08	-	-	-	-12,52	-71,97	-0,11	-387,92
International Aviation	-	-	-14,90	-	-	-	-	-	-	-	-14,90
Stock Changes	-11,44	-3,87	-1,22	-2,72	-	-	-	0,10	-	-	-19,15
Total Primary Energy Supply	**815,12**	**353,20**	**42,46**	**298,03**	**290,67**	**7,29**	**1,13**	**92,28**	**-41,30**	**1,00**	**1 859,90**
Transfers	-	6,07	-4,70	-	-	-	-	-	-	-	1,37
Statistical Differences	-2,78	0,17	0,00	-1,33	-	-	4,62	-0,27	0,00	0,09	0,50
Main Activity Producer Electricity Plants	-350,54	-	-0,32	-0,34	-289,70	-5,29	-0,93	-5,58	220,54	-	-432,15
Autoproducer Electricity Plants	-6,32	-	-	-0,16	-	-2,00	-	-0,37	4,70	-	-4,16
Main Activity Producer CHP Plants	-187,23	-	-1,63	-7,32	-0,97	-	-	-2,85	64,49	84,97	-70,54
Autoproducer CHP Plants	-55,71	-	-1,27	-19,69	-	-	-0,00	-6,33	29,72	10,46	-42,80
Main Activity Producer Heat Plants	-2,32	-	-2,46	-18,34	-	-	-	-0,99	-	20,87	-3,24
Autoproducer Heat Plants	-1,36	-	-0,04	-2,88	-	-	-	-2,30	-	4,73	-1,86
Heat pumps	-	-	-	-	-	-	-	-	-	-	-
Electric boilers	-	-	-	-	-	-	-	-	-	-	-
Chemical heat for electricity production	-	-	-	-	-	-	-	-	-	-0,03	-0,03
Gas Works	-18,05	-	-	14,71	-	-	-	-	-	-	-3,34
Petroleum Refineries	-	-362,58	359,87	-	-	-	-	-	-	-	-2,71
Coal Transformation	-47,46	-	-	-	-	-	-	-	-	-	-47,46
Liquefaction Plants	-	-	-	-	-	-	-	-	-	-	-
Non-specified (Transformation)	-	3,14	-	-	-	-	-	-	-	-	3,14
Own Use	-14,72	-	-11,39	-5,05	-	-	-	-	-32,39	-17,69	-81,24
Distribution Losses	-3,69	-	-	-3,15	-	-	-	-	-16,79	-18,53	-42,15
Final Consumption	**124,93**	**-**	**380,52**	**254,48**	**-**	**-**	**4,82**	**73,60**	**208,98**	**85,90**	**1 133,23**

PES

FES

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Tabular determination of objective function -2

Tabular determination consumption of Finally Energy Sources by consumer types:

Final Consumption	**124,93**	**-**	**380,52**	**254,48**	**-**	**-**	**4,02**	**73,60**	**208,88**	**85,90**	**1 133,33**
Industry Sector	**87,18**	**-**	**17,07**	**98,62**	**-**	**-**	**-**	**21,79**	**85,95**	**26,91**	**338,43**
Iron and Steel	49,44	-	1,43	11,67	-	-	-	0,02	11,01	2,21	72,61
Chemical and Petrochemical	24,01	-	1,94	8,04	-	-	-	0,28	12,41	8,46	55,14
Non-Ferrous Metals	0,17	-	-	1,32	-	-	-	-	1,17	0,08	2,66
Non-Metallic Minerals	8,60	-	1,39	27,22	-	-	-	5,04	9,51	0,57	52,19
Transport Equipment	0,38	-	0,04	6,04	-	-	-	-	8,26	2,36	17,08
Machinery	2,17	-	0,43	11,46	-	-	-	0,11	13,21	6,44	31,81
Mining and Quarrying	0,66	-	0,32	1,21	-	-	-	0,01	0,81	0,05	2,46
Food and Tobacco	1,77	-	1,64	11,76	-	-	-	0,12	5,89	4,49	25,08
Paper, Pulp and Print	2,48	-	0,71	4,04	-	-	-	10,21	6,37	1,59	25,40
Wood and Wood Products	0,02	-	0,28	1,00	-	-	-	5,56	1,89	0,44	9,21
Construction	0,12	-	2,63	3,39	-	-	-	0,06	1,60	1,19	8,99
Textile and Leather	0,77	-	0,20	2,43	-	-	-	0,07	3,12	0,81	7,40
Non-specified (Industry)	0,19	-	6,65	9,85	-	-	-	0,32	10,61	0,33	27,72
Transport Sector	**0,21**	**-**	**243,44**	**2,87**	**-**	**-**	**-**	**4,81**	**7,68**	**-**	**257,80**
Road	-	-	235,83	0,23	-	-	-	4,81	-	-	240,87
Domestic Aviation	-	-	1,95	-	-	-	-	-	-	-	1,95
Rail	0,21	-	4,49	-	-	-	-	-	3,94	-	8,64
Pipeline Transport	-	-	-	2,64	-	-	-	-	0,14	-	2,78
Domestic Navigation	-	-	0,17	-	-	-	-	-	-	-	0,17
Non-specified (Transport)	-	-	-	-	-	-	-	-	3,60	-	3,60
Other Sectors	**23,25**	**-**	**16,65**	**147,95**	**-**	**-**	**4,02**	**47,19**	**115,35**	**59,09**	**414,51**
Residential	19,62	-	0,75	85,70	-	-	3,63	44,17	52,94	38,73	245,52
Commerce and Public Services	3,09	-	0,67	52,62	-	-	1,19	2,26	50,19	19,98	131,99
Agriculture	0,56	-	14,15	2,24	-	-	-	0,77	3,48	0,37	21,56
Fishing	-	-	-	-	-	-	-	-	0,01	-	0,01
Non-specified (Other)	-	-	1,10	4,39	-	-	-	-	8,74	0,00	14,23
Non-Energy Use	**14,29**	**-**	**104,36**	**4,03**	**-**	**-**	**-**	**-**	**-**	**-**	**122,68**
Non-Energy Use Indus./TransfEnergy Sect.	14,29	-	99,28	4,03	-	-	-	-	-	-	117,60
Non-Energy Use in Transport	-	-	5,08	-	-	-	-	-	-	-	5,08
Non-Energy Use in Other Sectors	-	-	-	-	-	-	-	-	-	-	-
Memo: Feedstock Use in Petchemical Ind.	-	-	73,07	-	-	-	-	-	-	-	73,07
Elect.Output in GWh	**49 822,**	**-**	**131,00**	**2 910,00**	**26 551,**	**2 024,**	**258,00**	**1 460,00**	**-**	**-**	**83 185,0**
Elect.Output-main activity electricity plant	32 359,	-	29,00	37,00	26 551,	1 468,	258,00	548,00	-	-	61 349,
Elect.Output-autoprod. electricity plant	704,00	-	-	17,00	-	556,00	-	29,00	-	-	1 306,00
Elect.Output-main activity CHP plant	11 909,	-	68,00	579,00	-	-	-	103,00	-	-	12 357,0
Elect.Output-autoprod. CHP plant	5 151,0	-	35,00	2 297,	-	-	-	780,00	-	-	8 263,00
Heat Output-main activity CHP plant	78 089,	-	829,00	3 553,	970,00	-	-	1 549,00	-	198,00	85 187,
Heat Output-autoproducer CHP plant	7 729,0	-	347,00	1 977,00	-	-	-	1 032,00	-	903,00	11 988,0
Heat Output-main activity heat plant	2 380,0	-	1 976,00	15 766,0	-	-	-	737,00	-	94,00	20 973,0
Heat Output-autoprod. heat plant	819,00	-	45,00	2 171,00	-	-	-	1 884,00	-	5,00	4 724,00
Heat Output in TJ	**89 917,**	**-**	**3 196,**	**22 887,**	**970,00**	**-**	**-**	**5 913,00**	**-**	**1 200,**	**122 201,**

FEZ

Consumption

FES

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Determination of the ES objective function by the balance diagram

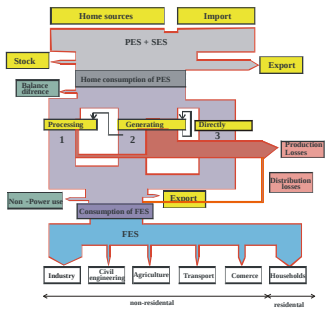
Sankeyův diagram **(balance diagram) is graphical presentation of the composition time course defined value of the system in the defined region. the author of this is Irish engineer Matthew Henry Phineas Riall Sankey (*1853 – †1921), who used it in 1898 for steam engine efficiency determination:**

- **Sankey diagram is used in technique for the presentation of any energy appliance .**
- **In the case of ES the monitoring value is work (energy).**
- **There is also able to presents the material movement, finance and people movement etc.**
- **Diagram is composed for the defined time interval T (period, day, year ,…), which in the ES case the Load Diagram - DZ_T^{ES}.**
- **The band diameter value presented the total value (absolute) of the monitoring value for the determined time.**
- **For the dynamic processes is Sankey diagram the clearest presentation of the continues process in ES, which is LD = f(t).**

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Objective function of ES Sankey diagram

Expresion of the total work amount consume for the defined period - 2005 year:

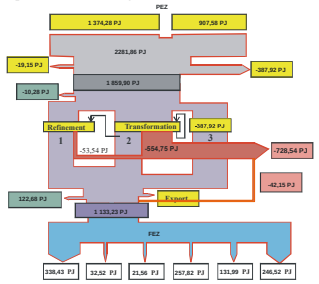


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Senkey diagram of ES Czech Republic - 2008

Expresion of total work amount by ES systém for defined period – absolute value LD_T:

- http://www.czso.cz/eng/redakce.nsf/i/home



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Evaluation criteria of the ES comparison

Energy efficiency indicators have multiple objectives, among which the 10 most important are:

- **Help to understand trends on energy consumption and energy efficiency.**
- **Provide market insights on the penetration of end-use equipment and energy efficient technologies.**
- **Benchmarking of energy efficiency performance of countries through cross-country comparisons, a crucial question in international negotiations on climate change.**
- **Setting energy efficiency targets**
- **Monitoring of the targets set at the national and international levels in energy efficiency and CO2 abatement programmes.**
- **Policy monitoring to evaluate the impacts of measures so as to justify the public money spent to support these programmes and to plan future measures and actions.**
- **Measure the long term impact of measures as these energy efficiency indicators can feed the technic-economic demand forecasting models needed, that are characterised by a high level of disaggregation (end-uses).**
- **Improve the dissemination of the progress achieved on energy efficiency, through dedicated indicators and tools .**
- **Finally, help measuring the multiple benefits of energy efficiency**

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Methodology for setting indicators

Indicators can be denominated in either physical units, where energy is directly related to the physical quantity of output, or alternatively in economic terms, where energy consumption is linked to the monetary value of production:

- **Indicators of energy efficiency can be constructed from aggregated international or national statistics through to output data from individual operating units within a plant.**
- **At the highest levels of aggregation - the whole economy and macroeconomic sectors - few indicators of energy intensity can be constructed.**
- **Moreover, due to the large level of aggregation, these broad indicators often include many separate effects that can potentially bias the results. For example, although declines in measured national energy intensities for many economies suggest improvements in energy efficiency, other factors, such as the declining importance of energy intensive sectors (structural change) and non-energy related efficiency improvements, also contribute to this result.**

Energy data for most economies (ES) came from the IEA's Energy Balances from OECD and Non- OECD Countries Database - International Energy Agency

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Relations of energy intensity indicators

Indicators define "how well" or only how many energy sources we have to use for realization of the compared output:

- **Indicators of ES energy intensity define "how well" energy imputes are utilized for the material production (which is made by FES utilization FEZ):**

I^{ES}_{it}=Energy Intensity of the whole ES = (PES total consumption in T period) / (GDP value made by FES):

$$I^{ES}it = \sum PES / HDP \quad [energy\ units / monetary\ units]$$

I^{ES}_{it}=Energy Intensity of electricity consumption = (Total electricity consumption in T period) / (GDP value made by FES):

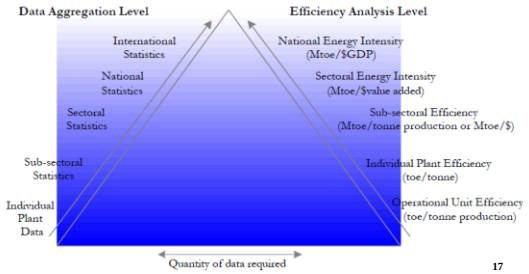
$$I_{it}^{FES,ele} = \sum FES,\ electricity / GDP \quad [energy\ units / monetary\ units]$$

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Quantity of data required for indicators construction

Moving further down the pyramid increases the understanding of the multitude of factors that affect more aggregated measurements of energy efficiency, and ultimately affect other variables such as national energy consumption:



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Determination of GDP by Production Method:

According to this method, GDP is defined as the market value of final production achieved in one year, on the territory of a given state:

- **We have to evaluate market production, while the sum of value added is made up of disparate products and services; GDP is given here by adding the number of products of individual types multiplied by the average market price according to the equation:**
  GDP = market price multiply amount of A product plus market price multiple amount of B product
- **Individual products and services that make up GDP are categorized into the following areas:**
  - ***C - final consumption*** **- (consumption [currency units]) - household expenditure on the purchase of goods and services, i.e. everything that citizens spend on shops and services,**
  - ***G – government*** **- government purchases of goods and services [currency units], i.e. everything that governments buy,**
  - ***I – investment*** **- gross private domestic investment [currency units], which is mainly investment purchases by companies, both for raw materials and for the expansion and renewal of so-called capital goods (i.e. also damage after the hurricane),**
  - ***X – exports*** **- [currency units],**
  - ***M – imports*** **- [currency units].**

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How GDP in relevant year can be published?

Prices and among of the seled goods are changing during individual year by follow year and made time row from past to present:

- **At current prices of the (prezent) year:**
  - **We take the prices p_i [monetary units] (for i=1 to n) of a given year („t"), i.e. the sum of current prices („c.p.") in this relevant year, and multiply it by the number of products in this year q_i. [number of units].**

    Such GDP is called Nominal GDP - or GDP in current prices :

    $$GDP_t = GDP_t^{c.p.} = \sum_i p_{i,t} * q_{i,t} \quad [currency\ units]$$
- **At the average prices of the previous year:**
  - **We can have GDP of the given year in the current prices (average) of the privies year („t-1"):**

    $$GDP_t^{CPPR} = \sum_i \bar{p}_{i,t-1} * q_{i,t} \quad [currency\ units] \quad GDP_t^{CPPR.}$$
- **At the constant prices of the reference year:**
  - **We are chaining of data in average prices of the previous year by the corresponding volume index:**

    $$GDP_t^{2000} = \sum_i \bar{p}_{i,2000} * q_{i,t} \quad [\text{monetary units}]$$

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Conclusion

Key Indicators		Compound Indicators	
Population (million)	10.27	**TPES/Population** (toe/capita)	4.49
GDP (billion 2000 US$)	72.50	**TPES/GDP** (toe/thousand 2000 US$)	0.64
GDP (PPP) (billion 2000 US$)	196.69	**TPES/GDP (PPP)** (toe/thousand 2000 US$ PPP)	0.23
Energy Production (Mtoe)	33.42	**Electricity Consumption / Population** (kWh/capita)	6511
Net Imports (Mtoe)	12.76	**CO_2/TPES** (t CO_2/toe)	2.63
TPES (Mtoe)	46.05	**CO_2/Population** (t CO_2/capita)	11.78
Electricity Consumption* (TWh)	66.85	**CO_2/GDP** (kg CO_2/2000 US$)	1.67
CO_2 Emissions ** (Mt of CO_2)	120.97	**CO_2/GDP (PPP)** (kg CO_2/2000 US$ PPP)	0.62

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