INTRODUCTION TO CLEANER PRODUCTION (CP) CONCEPTS AND PRACTICE

Group work exercises

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For UNEP, Division of Technology, Industry, and Economics

Lecturer Guide for Group Work

The use of group work is an essential part of most training courses and provides a good basis for trainee participation/ exchange of ideas and information. The exercises are intended to:

- enable participants to share their knowledge and experience with others;
- give participants an opportunity to apply information they have received from the lectures and to practice the critical skills in starting developing a CP project.

The chairman and secretary should be chosen in each group. The secretary should make sure that everything is written down in a proper form.

All options should be analysed and presented on the pieces of paper or overhead sheets. The group should choose a representative to present the Group work results and to answer questions (the group members should help him/her if some trouble appears).

Suggestions for Group Work 1.

At the beginning, you should ask participants to read the general information about possible processes and pollution in textile industry. After reading presented materials, participants should be allowed to ask questions for clarification. Therefore, it is advisable for the lecture to read additional materials about the textile industry before the training course.

General information about textile industry

Textile manufacturing begins with the production/harvest of raw fibber. Fibber used in textile industry can be harvested from natural sources (e.g. wool, cotton, flax) or manufactured from regenerative cellulose materials (e.g. rayon, acetate), or can be entirely synthetic (e.g. polyester, nylon). After the raw natural or manufactured fibbers are transported from the farm or chemical plant, they pass through four main stages of processing:

- yarn production;
- fabric production;
- finishing; and
- fabrication.

In yarn production, natural fibbers, predominantly cotton, wool and flax, are cleaned, carded and/or combed, and then spun into the yarn. Synthetic and cellulose fibbers are often supplied as staple – short fibbers similar to cotton, wool and flax– which are spun in a process similar to that used for cotton, wool and flax. Some of supplies are tow fibbers, which are composed of bundles of staple fibbers. The natural and synthetic fibbers can be combined.

The second step, fabric production, involves either weaving or knitting. Broad woven mills consume the largest part of textile fibber and produce raw textile material from which most textile products are made. Manufacturers of knit fabrics also consume a sizeable amount of yarns.

The third step is finishing. Most broad woven fabrics retain the natural colour of the fibbers from which they are made. In most cases, these fabrics must undergo further processing, which can include bleaching, printing, dyeing, mechanical finishing, preshrinking and shaping. Many different textures can also be obtained through the application of resins and sizing, and the use of high temperature and pressure. Finishing is important mainly in cotton, flax and synthetic production. For most wool products, some synthetic, cotton and linen products, the yarn is dyed before weaving; thus the pattern is woven into fabric.

Finally, the finished cloth is fabricated into variety of apparel, household and industrial products.

Textile processing generates many waste streams including water-based effluent as well as air emissions, solid waste and hazardous waste. The nature of the waste generated depends on the type of textile facility, the processes as well as types of fibbers and chemicals used.

Water Pollution

Textile manufacturing is one of the largest industrial producers of wastewater. Textile is also a chemically intensive industry. Therefore, the wastewater from textile processing contains bath residues from preparation, dyeing, finishing, slashing and other operations.

Air Pollution

Most processes performed in textile companies generate atmospheric emissions. Gaseous emissions are the second greatest pollution problem (after effluent quality) in the textile industry. Air emissions can be classified according to the nature of their sources:

- Point sources:
  - boilers are one of the major point sources of air emissions in the textile industry (NO_x, CO_2, CO, SO_x);
  - ovens, the highest levels of emissions by far come from ovens used in coating operations;
  - the lower levels of emissions come from thermo fixation, drying and curing ovens;
  - storage tanks, typically have open vents to allow equalization of internal and external pressures.
- Fugitive or area sources:
  - solvent based cleaning activities;
  - in wastewater treatment systems aeration of secondary activated sludge biological treatment lagoons strips most volatile components of the mixed liquor which are emitted from the waste treatment system;
  - warehouses can emit volatile emissions from process residues, especially printing or dyeing residues, or finishing chemicals that remain in the fabric;
  - spills can emit volatile pollutants for years.

Solid waste

By volume, solid waste is also on of the largest waste streams in textile manufacturing. The quantities of solid waste generated depend greatly on the size and type of textile operation, the efficiency of the machinery or process generating the waste, and the level of awareness about solid waste problems and management techniques among operators and managers in the company. Possible types of solid waste:

- ash and sludge from two major pollution sources: boilers and wastewater treatment plant;
- packaging materials (i.e. cardboard boxes, bags, wrapping film or fabric, baling wire, wooden crates, paper sacks and drums made of paper board, plastic or metal, etc.)

Hazardous waste

Most textile operations produce little or no hazardous waste as part of their routine operations, but a small percentage of textile companies are hazardous waste generators. However, any facility that uses chemicals can produce hazardous waste if a chemical exhibiting the hazardous characteristics of ignitability, toxicity, corrosivity, reactivity or flammability is spilled on the ground. The contaminated soil from such spill is often considered as a hazardous waste and must be handled accordingly.

Concluding remark

A brief overview of textile processes and the wastes that theses processes generate was presented although each process in different companies has its own unique wastes and environmental concerns. Therefore a systematic evaluation of each particular company and its processes should be carried out.

After participants have been familiarised with background information about textile industry, they can start analysis of the hypothetical case.

HYPOTHETICAL CASE STUDY

TEXTILE COMPANY "LTC"

General information about the company

The company was established in 1913 and is one of the oldest textile companies in a country.

Authorised capital	440 thousand USD.
Private capital	405 thousand USD (92.16%).
State capital	35 thousand USD (7.84%).
Annual turn-over	6.5 mln. USD.
Number of employees	1048.
Production area	25.000 m^2
Storage	5000m^2;
Territory	175.000 m^2;
Number of weaving looms	192;
Number of spinning machines	35.

The following items are manufactured at "LTC": 100% linen and cotton/linen fabrics for towels, bed linen, table linen, clothing, packing: non-woven linen, sacks linen, 100% linen yarns. Sewing department enables to produce consumer goods: bed linen, kitchen towels, table linen, curtains, aprons, bags etc.

The production of "LTC" is well known in country and abroad. The quality of products meets requirements of the country and European markets. 85% of production is exported to Sweden, Denmark, Italy, Germany, France, Finland, USA and Canada.

Lecturer should stress the importance of CP project organisation in the company.

Minimisation of waste generation and energy consumption with improvement of economical indicators has inspired the company to use systems approach/ CP concept to evaluate the environmental situation. The company made an assessment of its production processes from economical and environmental points of view.

The company's top management has made a commitment to support CP project and organised a CP committee responsible for implementation of CP project and co-ordination of all related activities. General director of the Company has confirmed a list of the committee members:

Chairman:	- general director;
Members	- technical director;
	- head of financial department;
	- chief technologist

The group has announced Environmental Policy statement.

JSC "LTC" Environmental Policy Statement

Environmental activities have a great importance in our company.
During the production processes the streams of hot and polluted air and water are generated; the boiler houses emitted to the atmosphere partial combustion products and hot smoke.
We are seeking to eliminate or reduce the consumption of hazardous materials and waste generation in all production processes and services, optimise the consumption of energy and water resources.
The pollution prevention at the sources is the main concept of our environmental solutions. In case it is not possible to avoid waste generation, we will try to reuse it or dispose in environmentally friendly and economically motivated way.

All employees have been informed about the company's environmental policy and have been invited to present proposals for its implementation.

The second step should be brief analysis of material and energy balance of the company: in case textile companies' representatives are present, brief comparison of energy and water consumption and wastewater amount should be done.

The production capacity of the company and volumes of the production in the last year are presented in the Table 1.

Table 1. The production capacity and volumes of the production in JSC "LTC"

No.	**Production type**	**Production capacity**	**Production in the investigative year**
1.	Linen and cotton/linen fabrics	7 millions m^2	3 833 millions m^2
2.	Linen bags	2.0 millions units	0.403 million units
3.	Non woven	1.5 millions m^2	0.217 millions m^2
4.	Linen yarn	420 tonnes	547 tonnes
5.	Short fibre linen yarn	1600 tonnes	378 tonnes

In the last year, 382 thousands metres of table linen, 1617 thousands metres of linen fabrics and towels, 274 thousands metres of linen clothing and 766 thousands metres of technical fabrics have been produced. The Company uses long and short linen fibre supplied by local and foreign companies.

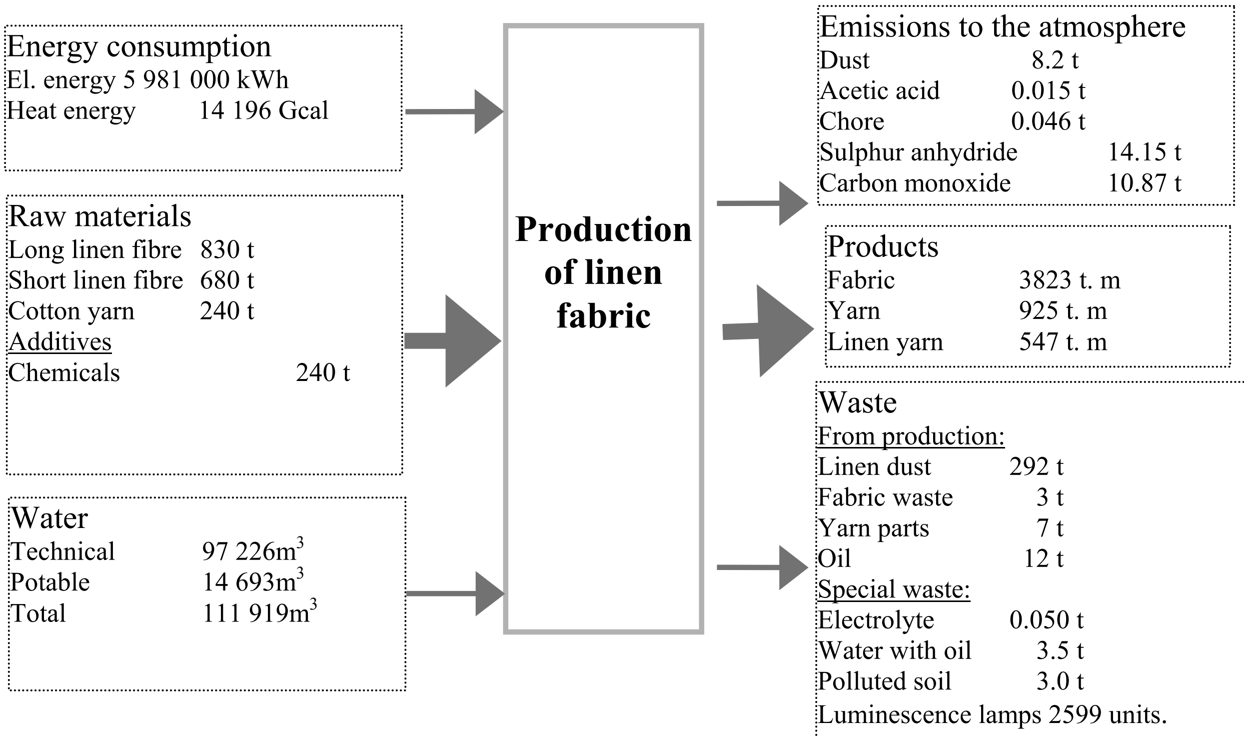


Fig. 1. Energy and material balance in JSC "LTC"

The Company "LTC" performs all processes of producing linen cloth:

- yarn production;
- fabric production;
- finishing; and
- fabrication.

Emissions of dust, chemicals and heat are consequences of intensive production of "LTC". Hot air and products of incomplete combustion are emitted from the boiler-house. Wastewater and air contaminated by chemicals are the result of insufficient process handling.

After the proper CP assessment the company's CP committee decided to take following actions:

1. ***Spinning preparation department***. In this department, raw material is cleaned, purified by forming filament and fibre. In the processes, two main environmental problems appears:
   - air is polluted by dust and raw material waste;
   - big amount of solid waste (boon) is generated.

   Polluted air is treated in filters (effectiveness 95 – 96 %) ***(End of pipe solution)***. As to gathered boon, the company decided to sell it to construction industry's companies as an insulation material ***(End of pipe solution).***

2. ***Wet spinning department***. In this department, the yarn's structural strength and integrity is formed. A single continuous filament yarn may typically have as few as one (monofilament) or as many as several hundred filaments. During the wet spinning process

(see scheme of wet spinning machine) two or more yarn from bobbins is passed through the reservoir filled with hot water or water and lubricator mix. Then the yarns pass through pair of rollers and onto rotating spindle. The yarn guide positions the yarn onto the spindle and assists in applying twist. In the twisting process, the twisting rings are manually lubricated with oil to ensure equal spinning ring speed (poor lubrication causes friction forces and affect quality of yarn).

The main environmental problem in this department is big amount of wastewater contaminated by oil and spinning solution. The lubricant is poorly degradable, therefore wastewater from wet spinning department significantly increases total pollution indices of the company.

The company decided to implement water and oil recycling (installation of oil cleaning filter and returning the oil to the process as well as water treatment equipment which enables to use treated water equipment for equipment cleaning) ***(CP option, on-site recycling)***.

Additionally, the idea to create special equipment for spinning ring lubrication and to change the manual spraying of the rings to mechanical was generated. The principle of the equipment is based on the following:

- The oil reservoir is hanged on the frame, which is moved along the spinning machine. The oil is sprayed at each segment inside the ring. This will allow to reduce oil consumption significantly ***(CP option, equipment modification)***.

Significant amount of water in this department was used for equipment cleaning: valves were installed in the columns i.e. on the ends of the water hoses. The workers used to open valve and go to the end of the hose to wash the equipment. When the job was done, the workers returned to the valve and closed it. In the process, "empty" run of water was 5 seconds in average. It was decided to install pistols at the end of the hoses and eliminate "empty run" of water. ***(CP option, good house keeping)***

3. ***In weaving department,*** significant amount of energy was consumed for lighting. The light was controlled by groups – for 6 – 8 weaving machines. A proposal to install individual lighting (3 lights (2*40 W)) for each weaving machine was generated. Therefore, it is possible to switch off the lights then the weaving machine is not in operation (due to different reasons, 25 weaving machines are not operating in average, i.e. 20%). ***(CP option, good house keeping)***

4. After CP assessment, the company decided to optimise ***heat production department***:
   - Significant amount of heat energy is lost in heat supply pipes going from boiler house to the non-woven fabrics department. It was decided to insulate the pipes. ***(CP option, good house keeping)***
   - Significant amount of heat energy was lost with smoke in the boiler house. It was decided to install heat utilisator, which acts to preheat the steam boiler's feed water by transferring heat from the flue gas stream as this stream contains excess heat from the combustion process. The heat utilisator can be referred to as an economizer because for every 5 ºC that the flue gas temperature is decreased, there

is one percent increase in the thermal efficiency of the company. As the thermal efficiency of the company increases, the plant saves money by utilizing the heat from an existing source instead of using heat from external source. ***(CP option, equipment modification)***

- Two steam boilers DKVR 4/13 (manufacturing data - 1984) are installed in the department boiler house. The boilers use oil as a fuel. Currently, the demand for heat is reduced and the steam boilers work inefficiently (capacity – 4 ton/h, real consumption – 1,5 – 2 t/h; high consumption of fuel, 10 employees for maintenance, substantial air pollution). Natural gas line is not built in the district. Therefore, the company decided to install a new steam boiler (productivity 2.5 t/h; coefficient of efficiency - 90%, pressure 10 bar, low atmospheric pollution, efficient use of electric energy, automated control). The old steam boiler will be dismantled and to the scrap sold. ***(CP option, equipment modification)***

5. The company generates large amount of wastewater, which is treated in the city's wastewater treatment plant. A decision to build local wastewater treatment plant was made. ***(End of pipe solution).***

Identify and classify presented options, dividing them in two groups:

- ***Cleaner Production or End-of-Pipe measures;***
- ***For Cleaner Production measures, identify the type of option: good housekeeping, technology change, input substitution, etc.***

The answers are provided in the brackets.

The participants should discuss each of generated options. It is recommended to initiate wider discussion about the idea to use the gathered boon in construction industry, because boon intended to be used off- site (see "What is not CP?).

Suggestions for Group Work 2. *New chairman and secretary should be chosen in each group. The secretary should take care that everything is written down in a proper form.*

All options should be analysed and presented on the pieces of paper or overhead sheets. The group should choose a new representative to present Group work results and answer the questions (the group members can help him if some trouble appears).

At the beginning you should propose participants to read and analyse the presented solutions. Afterwards, participants have to make necessary calculations, prioritise solutions taking into account economic and environmental considerations.

1. Installing economizer for a steam boiler TDA4000.

The company has built a new boiler-house in 1997.

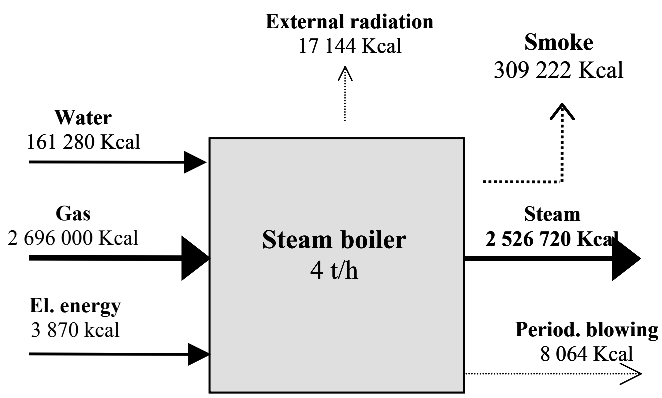


Fig. 1 Scheme before implementation

Scheme 1. *Energy balance of the steam boiler before CP project implementation*

Supplied energy: 2 861 150 Kcal
Produced energy:
Useful:
2 526 720 Kcal
+
Losses:
334 430 Kcal
Performance of the boiler: 88.3%

After review and detailed analysis of material and economic flow charts of the boiler-house, the company decided to install economizer for the steam boiler TDA 4000, which allows to recover part of the heat losses. The implementation costs of this measure consist of purchasing new economizer and its installation costs.

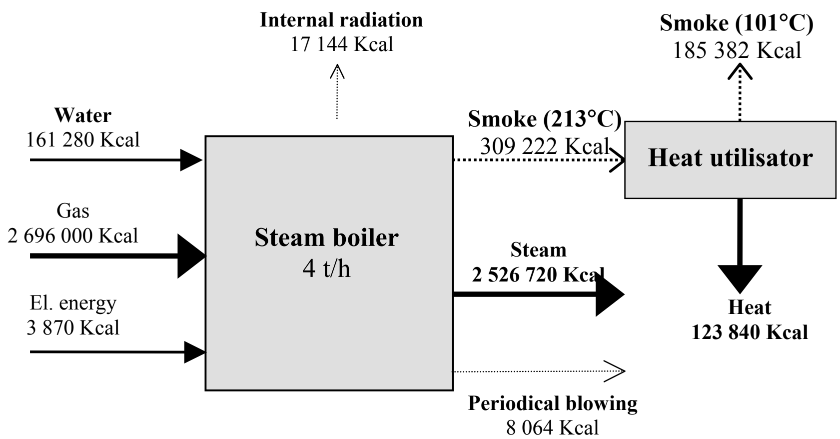


Fig. 2 Scheme after implementation

Scheme 2. *Energy balance of the steam boiler after CP project implementation*

Supplied energy: 2 861 150 Kcal
Produced energy:
Useful:
2 650 560 Kcal
+
Losses:
210 590 Kcal
Performance of the boiler: 92.6%

Calculation of the project results:

The energy balance *before* the project implementation:
Input:
Feeding water – 161 280 kcal
Gas - 2 696 000 kcal
El. energy - 3 870 kcal
Total amount of supplied energy – 2 861 150 kcal

Output:
Steam - 2 526 720 kcal (useful energy)
External radiation - 17 144 kcal
Smoke - 309 222 kcal
Periodical blowing - 8 064 kcal
Losses - 334 430 kcal

Energy balance a*fter* the project implementation;
Input:
Feeding water – 161 280 kcal
Gas - 2 696 000 kcal
El. energy - 3 870 kcal
Total amount of supplied energy – 2 861 150 kcal

Output:
Steam - 2 526 720 kcal (useful energy)
Heat from heat utilisator - 123 840 kcal (useful energy)
External radiation - 17 144 kcal
Smoke - 185 382 kcal
Periodical blowing - 8 064 kcal
Losses - 210 590 kcal

The energy amount saved per hour 123 840 Kcal
The boiler works 256 days per year.
Amount of energy saved per year is 256 x 24 x 123840 = 760 872 960 kcal = 761 Gcal
Project implementation costs = 12 450 USD
Savings on energy consumption = 14 128 USD/year.
Pay-back period =12 450 USD/ 14 128 USD = 0.88=10.5 months

2. Recycling of water and oil in the wet spinning process

Description of wet spinning process principles is presented in the Group work 1. Water and oil for lubrication are used in the wet spinning process. Currently, contaminated water by oil is partly treated in the separator inside the company and after primary treatment is released to the municipal wastewater treatment plant. Annually, 34 tones of lubrication oil and 21 000 m^3 of technical water are used in the wet spinning processes.

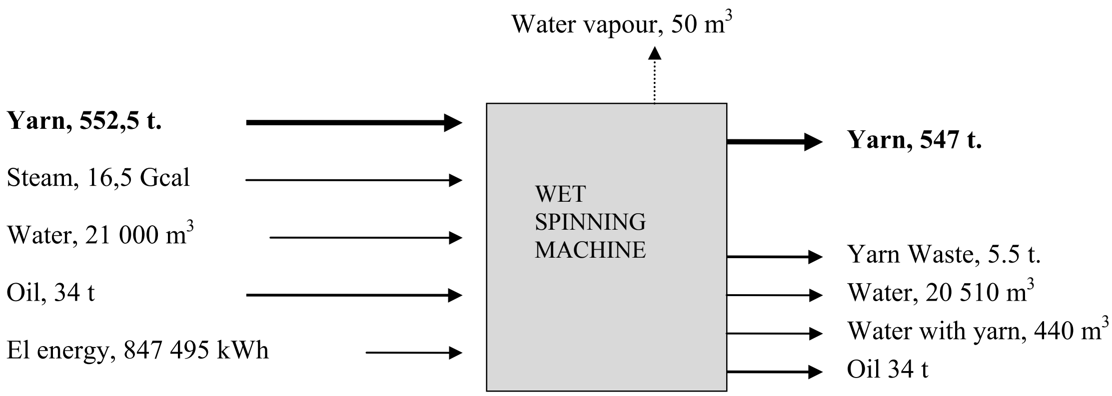
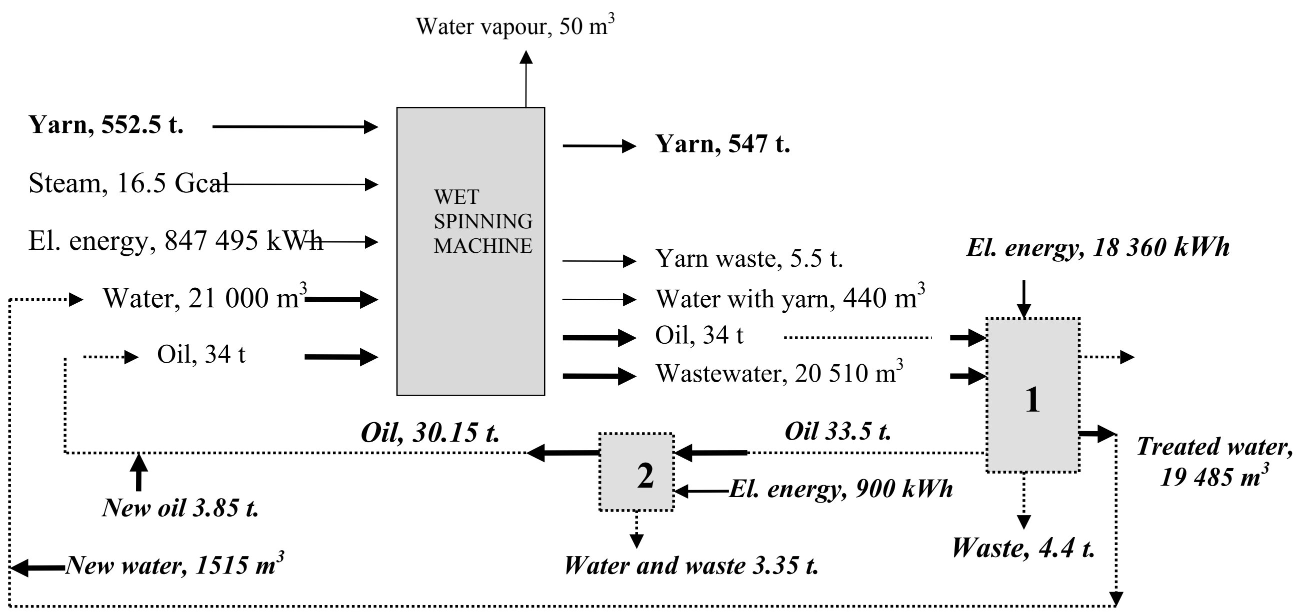


Fig. 3 Wet spinning process, before CP project implementation



1-equipment for water treatment ;
2 –oil treatment (IHDC4003 filter).

Fig. 4 Wet spinning process after CP project implementation

The essence of cleaner production proposal is to reuse water and oil from the spinning process, i.e. installation of oil cleaning filter to enable reuse of oil in the process and water treatment equipment to use treated water for equipment cleaning. The implementation cost consists of installing pipe network, wastewater treatment equipment, and oil cleaning filter as well as construction costs.

Calculation of the project results:

Amount of water saved per year - 19500 m^3;
Cost of water **1m^3 – 0.9 USD**
Cost of water savings 17 550 USD

Amount of oil saved per year - 30 t.
Cost of oil **1 t – 457 USD**
Cost of oil savings 13 710 USD
Cost of el. energy **1 kWh – 0,05 USD**
Consumption of energy increased 12 630 kWh
Cost of el. energy increased 631,5 USD
Environmental taxes reduced by **7 045 USD**

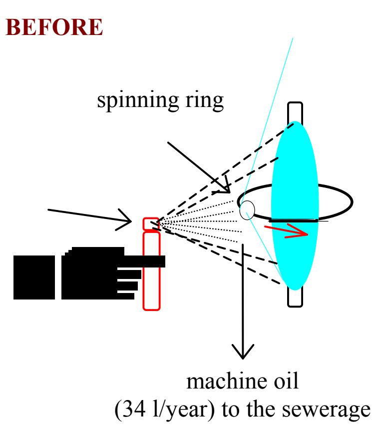
Project implementation costs = 27 822 USD
Total project savings = 37 673,5 USD/year.
Pay-back period =27 822 USD./ 37 673,5 USD = 0.74 = **9 months**

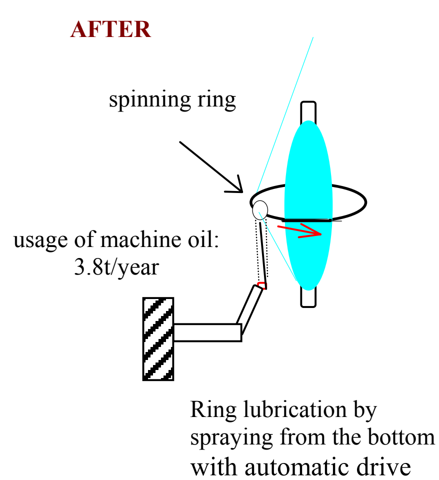
3. Improvement of ring lubrication system in the wet spinning machine

Another solution to reduce oil amount in the wastewater is to improve the ring lubrication system. Currently, lubrication is performed manually by operator. The largest part of lubricant is mixed with spinning solution and discharged to the sewerage system. The lubricant is poorly degradable. Therefore, wastewater from wet spinning department increases total pollution level of the company.

Additionally, poor ring lubrication influences the quality of yarns. Due to unequal ring spinning speed (poor lubrication causes friction forces) yarn twisting changes cause product spoilage. 34 tonnes of lubricant are used per year and only a small part of this quantity is used directly for its purpose – ring lubrication. The rest part is emitted to the sewerage system. The engineers of similar company have designed an automatic device for ring lubrication with spraying from the bottom:

> The oil reservoir is hanged on the frame, which is moved along the spinning machine. The oil is sprayed at each segment inside the ring. This modification will allow to reduce oil consumption significantly.





Calculation of the project results:

Amount of oil saved per year - 30 t.
Cost of oil **1 t – 457 USD**
Cost of oil savings 13 710 USD
Environmental taxes reduced by **7 045 USD**

Project implementation costs = 4 500 USD
Total project savings = 20 755 USD/year.
Pay-back period =4 500 USD./ 20 755 USD = 0.22 = **3 months**

Prioritisation of the proposals:

1. **Improvement of ring lubrication system in the wet spinning machine**
(Implementation costs: 4 500 USD; payback: 3 months; environmental performance: significantly reduced water pollution by oil products. From economic point of view the proposal is attractive due to small investments and short payback period)

2. **Installation of economizer for steam boiler TDA4000;**
(Implementation costs: 12 450 USD; payback: 10.5 months; environmental performance: significantly reduced energy consumption and reduced the air emissions in energy production sector (SO_x, NO_x, CO, CO_2). The proposal implementation costs are not high and payback period is relatively short.)

3. **Recycling of water and oil in the wet spinning process;**
(Implementation costs: 27 822 USD; payback: 9 months; environmental performance: significantly reduced the water pollution with oil products. Additionally water consumption is reduced (From economic point of view the proposal is similar to the second proposal).

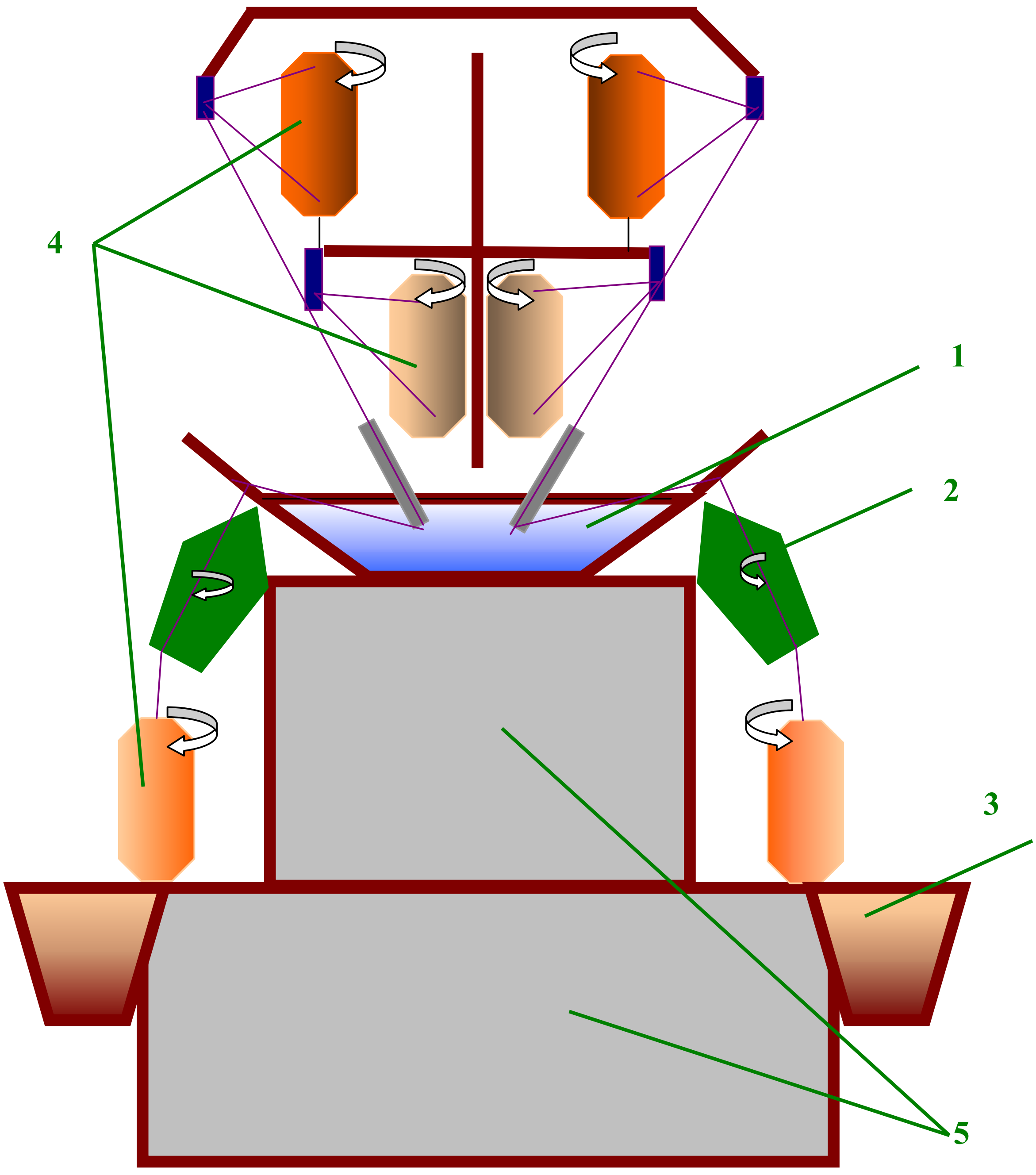
The participants can provide their own arguments based on their experience or local conditions. The arguments presented should be listed and discussed in the auditorium.

To demonstrate that CP is a continuous process it could be useful to underline at the end of the exercise that implementation of these three projects will not be the end of the actions of CP programme at "LTC". The company is committed to continuously improve its environmental and economic performance by implementing CP.

The following CP action plan has been prepared and approved by general director and technical director of the company:

No	Proposals	Deadline for implementation	Responsible person	Economic benefit
1	Installation of higher efficiency steam boiler	In two years	SC “LTC”, technical director	22 500 USD/year
2	Reuse of hot air from fibre dryer	In two years	SC “LTC”, heating/ventil. depart. manager	5 000 USD/year
3	Implementation of fabric bleaching line “Babcock”	In two years	SC “LTC”, technical director J.Astrauskas	217 500 USD/year
4	Continuously implementation of good housekeeping options with no or very small investments and periodic analysis of the company’s operations	Continuously	SC “LTC”, technical director	Calculated for a particular option

Wet Spinning Machine



1. **Spinning solution;**
2. **Twisting mechanism;**
3. **Wastewater (spinning solution, lubrication oil and yarn parts)**
4. **Bobbins**
5. **Mechanisms of wet spinning machine**