Chapter 11

Integrated Water Management Around a Large Chemical Platform

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Additional information is available at the end of the chapter

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1. Introduction

According to the EU Water Framework Directive (subsequently WFD) and its set of guidance documents [1,2], the main deadlines in implementing a coherent policy for water resources in the EU included:

a. By 2004 at the latest, each Member State had to produce an analysis (to be revised in 2013 and every 6 years afterwards) that must include:
   - an analysis of the characteristics of each river basin district;
   - a review of the impact of human activity on water and an economic analysis of water use;
   - a register of areas requiring special protection;
   - a survey of all bodies of water used for abstracting water for human consumption and producing more than 10 m^3/day or serving more than 50 persons.

b. By 2009, all Member States had to develop management plans for each river basin district, taking account of the results of the analyses and studies carried out in the previously mentioned analyses. These plans will cover the period until 2015, will be thoroughly revised in 2015 and then every 6 years thereafter.

c. The management plans must be implemented in 2012. These management plans aim specifically to:
   - prevent deterioration, enhance and restore bodies of surface water,
   - achieve good chemical status of water bodies by 2015 at the latest;
   - achieve good ecological status of water bodies, again, by 2015 at the latest, by eliminating / reducing pollution from discharges and emissions of hazardous substances;
   - protect, enhance and restore the status of all bodies of groundwater, prevent its pollution, and ensure a balance between groundwater abstraction and replenishment;

- preserve protected areas.

d. A specific mention is dedicated to how the management plans will be devised and implemented. The WFD asks Member States to encourage participation by all stakeholders in the implementation of this Framework-Directive, specifically with regard to the management plans for river basin districts.
e. Starting from 2010, Member States must establish water pricing policies that provide adequate incentives for users to efficiently use water resources and that the various economic sectors contribute to the recovery of the costs of water services, including those relating to the environment and resources. Member States must introduce arrangements to establish an effective, proportionate and dissuasive system of fines and penalties for the event of breaches of the provisions of WFD.

The WFD is a robust response that could be replicated in areas were irrational water consumption led to ecological disasters (e.g., the tragic fate of the Aral Sea [3]). But having a coherent legislation is only one part of the problem. Implementing it needs a dedicated work and collaboration among all stakeholders [4-8]. In taking decisions that affects the environment, the river basins ask for a high degree of responsibility and for a scientific, conservative approach [9], knowing that failing to carry out correct actions will lead to irreversible consequences at global level.

As an EU Member, Romania is committed to fully implement the WFD, and observe strictly all the deadlines in it. Adopting and inserting the WFD in the national legal framework was, by far, the easiest step in this process. As for implementing it, the number and dimensions of obstacles are important. Some of them are detailed below:

a. the Romanian industry inherited a very low effectiveness and efficiency because the majority of the industrial platforms, big water consumers, were built before 1990, when the concern about environment, resource conservation, water quality, etc., was limited. As a first consequence, industrial platforms could extract all the water they needed, sacrificing in many cases the habitat, the quality and quantity of groundwater, the needs of communities;
b. Very little attention was paid to polluting water bodies so that at present, in many areas, the rivers and the underground water content in fertilizers, insecticides, nitrates/nitrites and other chemicals, etc., is unacceptably high;
c. Though one may say that Romania has enough water resources for its industry and habitants, recent drought years revealed the dangers hidden in this assertion and asked for swift and coherent measures and plans in order to efficiently manage the existing water resources, without compromising the environment;
d. There is little or no co-ordination and communication among all stakeholders using water from the same river basin or from the same underground water body. Establishing an industrial facility, a hotel or touristic resort in a given location does not take into consideration the detailed, long-term impact impact upon the water resources of the area and the consequences for all other stakeholders already consuming water from the same sources;

e. At enterprise level, the water management is in almost all cases reactive, i.e., the management responds to penalties, fines or other enforcing measures taken by the Romanian Environmental Guard or similar enforcing bodies. Pro-active policies at enterprise level are scarce, uncoordinated with other stakeholders, inefficient since they include only the interest of a given company;
f. There is a lack of practical tools (mathematical models, data mining, benchmarking procedures), at enterprise level that can manage the water resources in the same way in which fuel or raw materials are managed. Though available, detailed and comprehensive, reference documents [10] are not, in many cases, used in day-by-day work on industrial platforms;

The paper presents the outcomes of a Project carried out in the period 2009-2011, having as general objective the implementation of the WFD at a chemical platform (including the surrounding areas and stakeholders).

Specific objectives were:

- Set up a task force, at local level that can take care of the WFD specifications and deadlines even after the Project will end;
- Know-how transfer to the mentioned task force (management tools, mathematical tools, specific indicators connected to all aspects of water management);
- Establish a mode of cooperation among all stakeholders interested in the sustainable use of the same water sources.

The Project was coordinated by the Romanian National R&D Institute for Industrial Ecology (INCD-ECOIND), Bucharest.

Its role in the Project was to:

- establish the focal area of the project;
- set up a Project Advisory Board that will guide the Project team and assess its results;
- carry out an interactive SWOT analyses, with the help of local experts and managers;
- devise, together with the local experts, material balances for water, in the focal area;
- set up a mathematical model for optimal use of water in the focal area;
- run and analyze various scenarios in order to test the model usefulness and validity.

Though some of the processes in the focal area were analyzed against best available techniques and some options for reducing water consumptions were generated, the main focus of the Project was to articulate a management system that includes all the important water users in the area and to optimize the water use at the level of this system. The optimization of each inner component of the structure of the system was not the objective of the present Project (only the VIROMET platform subsystems have been considered). The main reason for this limitation is that a mathematical model that could carry out the optimization of a system including many imbricate subsystems (companies and other water users) needs the knowledge of many technological parameters of each consumer. Many of these parameters are confidential. Nevertheless, by providing ranges of consumptions by each system component, companies that constitute the system studied could infer relevant conclusions about how big their share in the system is and how they could contribute to its sustainability.

2. The VIROMET Water Management System

The first task of the Project Team was to clearly establish the borders of the system to be scrutinized. This led to the Water Management System centred on the VIROMET platform (subsequently VIROMET WMS), illustrated in Figure 1.

Mainly, it includes:

1. multiple water intakes from adjacent rivers. The intakes are owned and managed by VIROMET;
2. a pre-treatment station that produces water for technological purposes (industrial water streams in Figure 1). The station is owned and operated by VIROMET;
3. s system of distributing the industrial water to all industrial stakeholders, namely:
   a. a ion-exchange resin factory (Platform B in Figure 1);
   b. several SMEs in the vicinity of the VIROMET platform;
   c. a station for producing drinking water, subsequently used internally by VIROMET or distributed to Platform B and other users, including small communities. The Station is owned and operated by VIROMET;
   d. multiple industrial installations, components of the VIROMET platform;
4. a wastewater treatment station that collects wastewater from a number of surrounding water users. The station is owned and operated by VIROMET. Wastewater from the SMEs that take industrial or drinking water from VIROMET WMS is not collected and processed by this station.

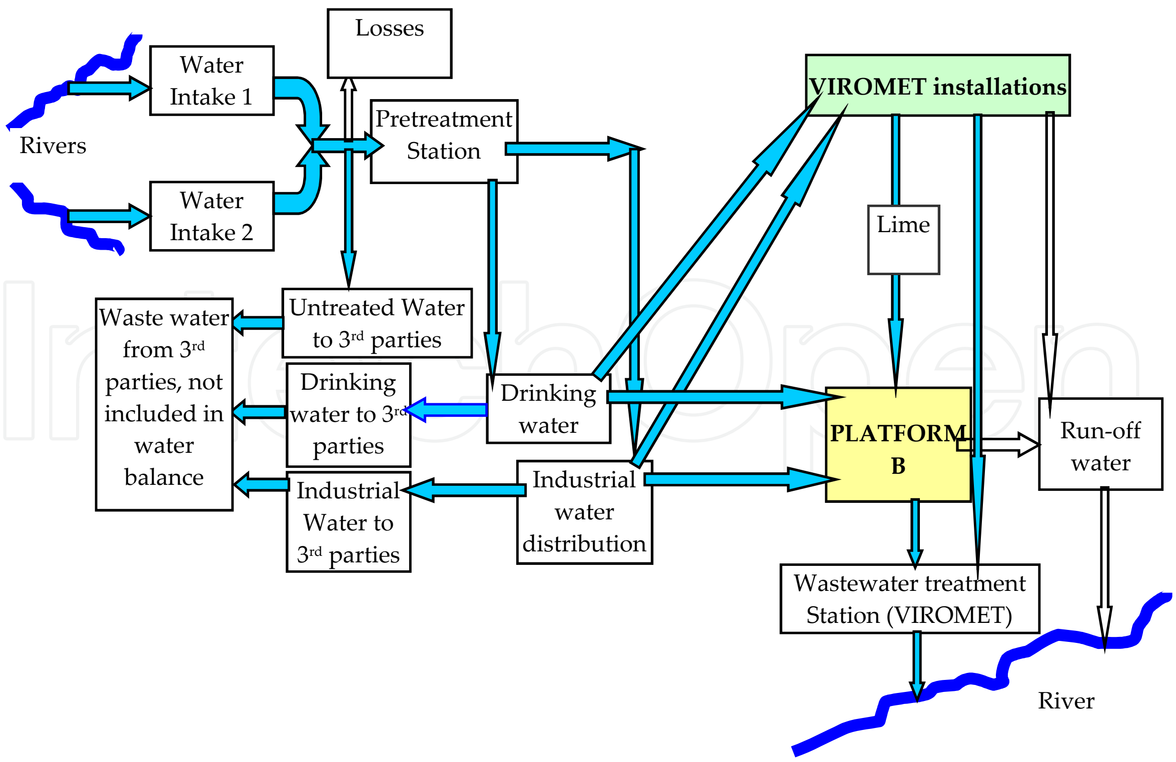

Figure 1. The VIROMET Water Management System structure. Dark arrows denotes measured or estimated flows

As a first remark, VIROMET is the main provider, the main consumer and the single wastewater operator in the area considered.

The water intake facilities, the pre-treatment and drinking water stations owned and operated by VIROMET provide 3 different qualities of water for end-users:

- water taken from the rivers, delivered as is to consumers;
- industrial water (for technological uses). This includes also the advanced purified water (deionised) used by local boilers.
- Drinking water distributed to local industrial consumers and to adjacent communities.

This being the situation, the main focal point of the Project was the VIROMET platform.

This is a very large chemical platform, founded by Czechs in 1937, then operated by Germans and used during WWII. After 1990, the portfolio of installations and products was constantly shrinking, mainly because the capacity of the platform was correlated to other industrial consumers that ceased to exist. At present, VIROMET is a private company, listed on the Bucharest Stock Exchange. It has some 850 employees (in 2009) and a turnover of 33 MEuro (2008). For the needs of the presdent project, the following main sections of the platform have been included in the study:

1. The Methanol installation;
2. The resin production facility;
3. The plastic ware installation (canisters, barrels, other similar products);
4. The R&D, small scale production installation;

3. The project task force

Following the WFD specifications, the Project aiming at establishing a performing water management system in the VIROMET area had to identify and include all relevant stakeholders and establish a procedure of consultation, cooperation and coordination among them, a rather new approach for the Romanian business environment, but a must, in the lines of the WFD.

The identified stakeholders were:

- The VIROMET Company, the main focal point of the Project;
- Another, adjacent chemical platform, producing adsorbents and ion-exchange resins – the second major water user (Platform B in Figure 1);
- Several SMEs interested in constant and good quality water feed from the VIROMET water intake and pre-treatment system;
- Adjacent small communities. It must be underlined that the location of the VIROMET platform is in the vicinity of the Fagaras Mountains, the tallest in Romania (+2500m), an area still covered by large virgin forests, with many protected zones for plants and animals. The beautiful landscape provides large resources for developing touristic activities in the area and, in fact, especially after the year 2000, many touristic facilities

have been commissioned (hotels, winter sports services), especially by private investors. This new and abrupt development of the zone, without accurately, objectively evaluating the short and long-term resource potential of the area, led to additional stresses upon the water resources (rivers, underground resources). All water management systems must therefore integrate these end-users, in trying to evaluate their contribution to the water footprint and limit, minimize and repair the damage done to water resources.

In order to accurately evaluate the situation of the water resources in the focal zone and to take into account the interests of all stakeholders, it is recommended that a Project Advisory Board (subsequently, PAB) be set up at the beginning of the Project.

This PAB has the following characteristics:

- It consists of recognized, uncontested personalities in the area (managers of large companies, reputed specialists, local mayors, retired experts). The PAB must enjoy an intrinsic legitimacy, unanimously accepted by the local people;
- Their role is to guide and censor the Project team members during the Project implementation by analysing the pertinence of their findings, their suggestions, their initiatives. In order to be accepted and implemented, these initiatives must not contradict the history, traditions, customs of the local people and communities, must preserve the specificity of the region; members of the PAB are believed to be in the best position to know exactly what is best for the local people, from the point of view of preserving water bodies and the beautiful surrounding environment;
- Members of the PAB are in no way remunerated by the Project. Their participation is fully voluntary but will impact upon the local people in the focal zone.

4. The existing situation. SWOT and DPSIR

A detailed SWOT analysis was carried out by the Project team. Main findings are included in Table 1. Issues in Table 1 are, in majority, available for all chemical platforms in Romania.

Nr	Internal factors		External factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
1.	The platform is in the vicinity of important river courses, easing the water intake operations	The pre-treatment technologies and equipment need upgrade. Consumptions in some modules of the system are not measured but only roughly estimated.	Restructuring the water management system will be made in line with last minute norms and most advanced technologies [10-12]	Climate change induces major events at an accelerated pace (drought, flooding). Retrofitting should take into account new conservative capabilities for water management.

Nr	Internal factors		External factors	
	Strengths	Weaknesses	Opportunities	Threats
2.	Water distribution and wastewater collection system have extra capacity, due to the shrinking of the activity of the platform. Existing extra capacity assures that there are enough places for expanding the industrial activity in the focal area.	Maintaining and operating a water distribution and wastewater collecting systems not adjusted to the exact needs of the users is very costly.	Any new investment in updating the water distribution and collecting network must be aligned to foreseeable trends in UE, about water resources so it will fit the long term requirements for the water networks.	There is little communication, coordination, no integrated management system of water resources in the focal zone. Uncorrelated use of water can lead to major disfunctionalities, especially in a drought year.
3.	The personnel operating the water and wastewater system is very experienced and skilful.	Existing water network cannot recycle water on the platform (no pumping facilities, no dedicated recycle piping). Practically, the water flows in a single direction, without recycling loops that could increase the efficiency of the system and reduce associated costs.	Opportunities to access EU funds for retrofitting the water system	Adjacent communities are exposed to risks caused by poor operation of the wastewater treatment facilities in the focal zone. Water and soil polluted with chemicals may affect large areas, reducing the touristic potential and gravely affecting the environment and public health.
4.		Many technologies (especially small scale ones, used in SMEs) in the focal zone are not aligned to BAT, mainly because the production level does not legally impose such an alignment. Consumption is therefore inefficient for many installations. This adds to stress upon the water resources and also increase the amount of wastewater to be treated.	Investment needed for updating the water and wastewater networks in the focal zone could be supported, partially, by other stakeholders, via some mutually beneficial arrangements with VIROMET (public-private ventures)	Environmental norms in Romania are aligned to the EU ones. But this reduces the profit of Romanian companies, by comparison with industrial facilities not observing these norms, situated in other geographical zones (outside EU, CIS, Asia, etc.)

Nr	Internal factors		External factors	
	Strengths	Weaknesses	Opportunities	Threats
5.		The parameters assured by the wastewater treatment station are difficult to monitor or modify, in case the legal limits for pollution will become stricter (instrumentation of the stations is in many instances inadequate).	The platform can offer technical assistance, maintenance and expertise to adjacent water users in the field of water distribution and wastewater collecting networks	Not having a sound water resource management system will add to the financial burden of the Company, since Banks become more interested in the level of environmental concern of their clients
6.		There are no identified and implemented options for water reuse outside the platform (irrigation, sport facilities, etc.). Neither the residues of the wastewater treatment station are used in any way.		There is a gap between enforcing agencies and enterprises. Instead of acting together, coherently, joining forces, learning one from another, they act as enemies. This does not add to the know-how and awareness of the companies.
7.		There is neither sound and comprehensive strategy nor specific managerial, operational tools that can lead to more effective and efficient water use (DPSIR evaluation [13], eco-efficiency indicators, environmental management accounting [14], etc.).		

Table 1. Main findings of the SWOT Analysis

The most coherent way to evaluate critically and in full detail the existing situation in the focal area is the DPSIR approach [13].

A multitude of DPSIR indicators were collected or derived (population, density, geographic area, climate, household area per person, unemployment, criminality, cars / 1000 inhabitants, sanitation, water supply characteristics, emissions to air, water, soil, etc.), but they will not be described here

The objective of using DPSIR was threefold:

- to test the potential of an analytical framework, recommended at EU level, in a practical case;
- to get the specialists of the focal zone used to a powerful tool, to exercise such an analysis whenever need be, not necessarily in the case of water management but in any environmental studies;
- to generate a basis for future DPSIR assessment that will evaluate the trend of the processes and pressures in the area.

For the structure and elements of the DPSIR approach, see Reference [13].

Essentially, the DPSIR tries to find objective responses to the following issues:

- *What is the state of waters in the focal zone?*
  - Quality? (Nutrients, pesticides, heavy metals, ecological quality)
  - Quantity? (Runoff, availability, demands, water stress)
- *Dynamics of water bodies*
  - Is the situation improving or getting worse, year by year?
  - Are the trends observed leading outside the legal limits?
- *What are the causes of the problems?*
  - Industrial
  - Agricultural
  - Human Communities
  - Pressures on the environment
- *Policies*
  - Are they the right ones, effectively and efficiently working towards targets?

The DPSIR evaluation carried out in the focal zone pointed out the aspects included in Table 2.

DPSIR element	Structure	Findings
Drivers	Industry	Large chemical platforms and diverse SMEs in the area operate technologies difficult to control (e.g. bakers using polluting additives, car service stations improperly disposing of paints, batteries, wastewater) The City of Victoria depends in great measure on the success and sustainability of the VIROMET platform, because a large share of the active population works for VIROMET. There are few other opportunities for employment in the area.
	Energy	VIROMET Power plant operates on gas
	Agriculture	Large areas of maize, potato, vegetables, wheat cultures, orchards
	Animal breeding	The area includes large pastures for livestock and is particularly renowned for the quality of dairy products from cows, sheep.
	Aquaculture	Trout breeding facilities commissioned, especially during the last decade

DPSIR element	Structure	Findings
	Households	The general trend is for population to move from agglomerated cities to a country side that is very far of being prepared to host them. Little or no sanitation or sewerage systems available, no environmentally sound landfill facility.
	Tourism	The area has a large touristic potential
Pressures	Climate change	Last 20 years included several drought years and flooding events as well in Romania but the focal zone was little affected
	Point source pollution	Accidental
	Diffuse source pollution	Mainly from households that irrationally use fertilizers and insecticides. Increasing awareness, education, trading must contribute to sort out this complex problem.
	Water abstraction	Not subject to any regulation or voluntary agreement by individual households
State	Water quantity	Could support the existing level of human activity, but not in case of extreme climatic events. All future development of the area must align to a coherent Action Plan
	Groundwater status	A large number of analyses carried out by ECOIND showed that the groundwater is polluted in many areas, especially with oil products, chemicals, fertilizers and the like. Nitrites-nitrates level too high.
	Ecological status	Acceptable, improving but needs permanent monitoring
	Chemical, physical, biological	Large industrial platforms and service companies (e.g., gasoline stations) have induced soil and underground water pollution in many areas
Impacts	Loss of habitats/species	Irrational deforestation led to reduced habitat areas
	Ill health	No reported illnesses specifically connected to the state of water
	Droughts/floods	Potential for drought or floods that would have grave consequences upon the communities
	Loss of amenity	Potential loss of amenity very high, due to incoherent development of the focal zone, especially of household buildings and touristic facilities
	Eutrophication	Present in some small rivers, near pollution sources
	Acidification	Present in some small rivers, near pollution sources
Responses	Water use restrictions	Little cooperation among stakeholders
	Alternative supplies	Need large investment. The capacity of the VIROMET water providing system seems enough for the period to come
	Subsidized water prices	Water intake from underground, by individual households not measure or paid for

DPSIR element	Structure	Findings
	Improved information	Needed by all stakeholders
	Demand side management	Not present
	Voluntary agreements	Not in operation
	Regional conflicts	No
	Waste water treatment	Yes, but only for major industrial water users. Small communities still wait for sanitation, in-expensive wastewater treatment facilities

Table 2. DPSIR findings.

The conclusions of the preliminary evaluation of the water resources in the focal zones are:

- The City of Vitoria and other small communities depend on the fate of the VIROMET platform
- Though the water sources seem to cover the present needs of the industrial activities and of the communities in the VIROMET WMS, there are obvious pressures upon this system, due to rapid development of the small communities and touristic facilities that must accommodate more and more people coming from large cities. Future industrial investment in the area will add more stress upon the water bodies under scrutiny;
- There is a need of coordination of action of all stakeholders, in order to implement a rational framework for water use that preserves the environment in a particularly sensitive area;
- "Historical" pollution (caused by industrial platforms operated before 1990, without any environmental concern) must be confined by taking special measures (barriers installed in soil, extracting and purifying the underground polluted water).
- There is plenty of room for improving the water management in the focal zone by reducing consumptions, by improving the industrial technologies operated in the area (especially in SMEs), by increasing the awareness and limiting the irrational use of fertilizers, pesticides, and the like;
- By applying the DPSIR framework of analysis, managers realize that they have at hand a procedure that indicates the causes, impacts and places of actions in order to improve the water system performances. The approach is straightforward and accessible, yet thorough and comprehensive.

The following section will show how the Project team tried to improve the water management in the focal area.

5. Internal benchmarking and alignment to BAT

Benchmarking is a management technique that consists of permanently searching and implementing of significantly better practices than those currently in use in a given area. It leads to better performances by investigating the performance and practices of other organisations (benchmark partners) [15].

Benchmarking is key to creating crisis that facilitate the change process in an enterprise.

Applying benchmarking techniques has the following advantages:

- Employees are able to perceive the improvement, in the short term;
- Increase responsibility of the personnel and challenges operational complacency;
- Points to weaknesses and suggest what actions are required to get better;
- Creates a motivating atmosphere leading to continuous progress;
- Generates a challenge to attain and go beyond the performances of competitors;
- It is a permanent source of realistic and achievable targets.

As can be seen, benchmarking uses comparison and reference to other benchmarking partners, but in a zone where the state of equipment and the level of technologies is not quite state-of-the-art, putting side by side the performances of benchmarking partners and the results of the company that is searching for improvement may be discouraging. It could become obvious that the improvement one is searching for is not possible without huge investment and would be achieved only after large time delays.

The Project team chose, instead, the internal benchmarking approach. As a first step, before comparing to others, the managers would have to identify the best performances recorded by the company itself. As those performances were recorded, they have been attained without any investment or new technologies, only by carefully operating the existing equipment, paying attention to all details, fully respecting the operating procedures. It is the task of company and installation managers to identify the best results and performances (benchmarks) achieved by the company and analyze how they were possible. By simply putting order in the operational stage, by motivating personnel to responsibly carry out their work, the company could align its performance to its own best level, already recorded.

To illustrate the procedure, in the case of VIROMET WMS, Figure 2 shows the production of the platform and the water consumption to achieve that production, all data expressed in % from average yearly values.

The conclusions of Figure 2 are obvious:

- the water consumption follows the water production profile but there are marked deviations from average;
- The specific consumption varies reaches a lowest 87% of the average value, instead of being practically constant, all the year long;
- The benchmarking emerging from this figure is the month of April, where the performances of the platform were the best;
- Analyzing the consumption data in connection with the production parameters and with all operational data recorded, managers will have to identify why the specific consumption could be as low as 87% of the average value. By simply identifying and

observing the conditions that led to the lower specific consumption, the platform will see its water specific consumptions decrease by 13%.

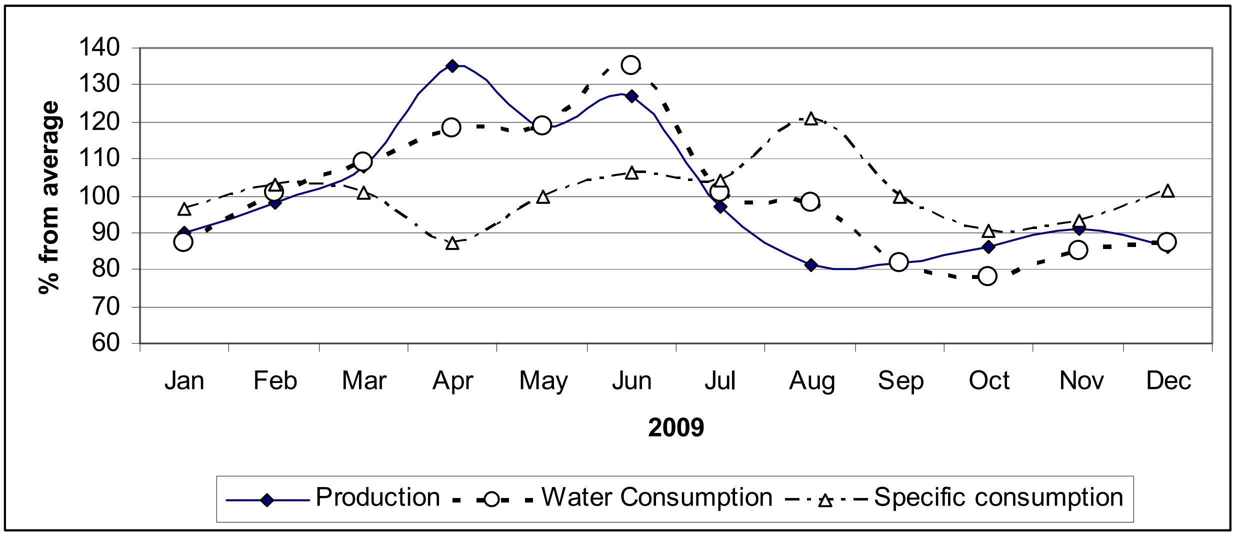

Figure 2. Monthly production and water specific consumptions.

Cleaner Production options generated during the comparison of the existing technologies with BAT produced a list of actions to be taken by the platform managers in order to improve the installation performances.

The list included:

- Tangible elements:
  - Proactive maintenance;
  - Use of piping and instrumentation from non-operational units to increase the performance of the operational ones;
  - Installing additional measuring devices in order to monitor the water consumed in places where there is poor instrumentation and control;
  - Replacing the ceramic bed in the absorption towers with more efficient packings;
  - Water flows that may be recycled on the platform, instead of being directed to the wastewater treatment facility. Though this will call for investment (piping, pumps, some heat-exchange equipment), it is estimated that this will lead to no more than 4-5 years return on investment;
  - Establish points of intake for monitoring the water quality in the VIROMET WMS;
  - Identifications of water flows that could be send to adjacent consumers (for irrigation purposes) instead to be sent directly to the wastewater treatment station or directly to the river.
- Intangible elements
  - Training the personnel, especially the operators of the water system;
  - Motivating the operators;
  - Direct R&D efforts toward reduction of water intake;
  - Encouraging innovative solutions from operators;

- Increase the know-how and expertise: ask personnel to assist operators in other installations, in order that everyone becomes aware of the problems confronting the entire platform.

6. Optimization of the Water Management System

In order to optimize the performances of the water management system at the focal point, the Project Team chose to develop a mathematical model comprehensive enough, so that its results are useful for the local managers but simple enough in order for the same managers to understand it, apply it and contribute to its improvement.

There are many software products that can design, model, simulate, and optimize water and wastewater systems at different scales [16-18]. Instead of using a software that comes as a black box that no one can access and understand how it works, the Project team chose to use the facilities and tools offered by the MICROSOFT EXCEL software, already existing in many companies and much more accessible and intuitive.

The MICROSOFT EXCEL software includes a mathematical package that can solve linear and non-linear programming problems, given a minimal set of data that must include:

- the optimization criterion (to be minimized, maximized or set equal to a prescribed value);
- the design variables (that must be adjusted in order to get the optimal value of the optimization criterion. The design variables are, e.g., water flowrates among different parts of the VIROMET WMS, productions of the VIROMET WMS components, etc.:
- the set of model parameters (e.g., cost of unit of water, cost of treatment of 1 m^3 wastewater, specific consumptions per physical unit of different products of the VIROMET WMS, etc.);
- a set of restrictions that take into account that production capacities are limited, piping transporting capacities are limited, water amounts needed by different users must observe some minimal and/or maximal levels, all water flows must be non-negative, etc.

The structure of the mathematical model is detailed in the subsequent paragraphs, for the case of minimizing the water consumed by the VIROMET WMS by linear programming [19].

The model is based upon the following assumptions:

- it considers and includes 4 sections of VIROMET (Methanol, R&D, Resin, Plastic ware)
- because of confidentiality reasons, the contribution of other water consumers is included in the mathematical model in the set of restrictions (e.g., a consumer will not accept a water flowrate under a given level and is not interested in buying water over a given level. These minimal and maximal levels are included in business contracts signed by VIROMET as this is the water provider of other stakeholders. In principle, the model could be easily expanded to include and optimize processes at any water

consumer in the focal zone, by simply adding extra terms (design variables) to the optimization criterion and by expanding the set of restrictions. Yet such a process needs a total transparency and access to data that are confidential at every partner in the water management system studied;

- cost levels are those available for the 2010 year but the MICROSOFT EXCEL application can be readily include new, adapted cost values without problem.

The application is set to minimize the following criterion (written in condensed format):

$$\min_{P_i} \sum_{i=1}^{4} P_i \times w_i$$

Here, P_i is the production of a given component (i) of the VIROMET WMS and w_i is the water consumed per 1 unit of product.

The set of restrictions are:

- Productions vary between two limits: a minimal threshold (generally = 0 but the managers may consider to adopt different minimal threshold, if, e.g., based upon past years, they are sure that they could sell a minimal production) and a maximal level (generally the production capacity of a given installation but, again, managers are free to choose any limits they consider suitable)

$$P_{i,\min} \le P_i \le P_{i,\max};$$

Here the index *min* and *max* refers to the already mentioned minimal, maximal thresholds for the productions

- In the case of other optimization criteria, different restrictions may be used. For example, the industrial water consumed will vary between a minimal value (e.g., 0) and the maximal capacity of the water transporting network or of the water treatment installation. The upper value could also include limits imposed by climatic events (the water amount will then be, for example, an acceptable fraction of the available river flowrate, fraction that will preserve the environment and ensure enough drinking water for the communities);
- Freshwater consumed on the platform will also obey similar restrictions:
- All variables are non-negative

$$P_i \ge 0.$$

As can be seen, there is no fixed structure for the optimization criteria and for the set of restrictions. In this way, a simple MICROSOFT EXCEL application is flexible enough to suit many cases of interest for the local managers / stakeholders.

Table 3 illustrates the simplest way to use the model: the managers wish to know the exact amount of water needed to produce a given quantity of a product, by one of the members of the water system. Such a facility of the application is necessary when there is an opportunity to sign an additional contract with a client, situation in which the managers should know what that contract will add to the existing structure of the water consumption.

Calculated parameter:	*Water consumed, m³*	***894380***
Productions, tons	**Value**	
Methanol	75000.00	
Water consumption	**Value, m³**	**Max available**
Industrial water	892757	1200000
Freshwater	1623	20000
Total	894380	
Water available	**Value, m³**	
Industrial water	307243	
Fresh water	18377	

Table 3. Scenario 1: amount of water needed for a given production

As seen from Table 2, the platform still have 307243 m³ of industrial water and 18377m³ of fresh water available for other fabrications so the additional methanol production will be possible without any problems.

Table 4 is the result of the application put to minimize the water consumed by the VIROMET WMS.

Optimized Criterion:	*Water consumption, m³*	***932435***
Productions, tons	**Value**	
Methanol	35000.00	Contracted
R&D	0.00	
Resins	40.00	Contracted
Plastic ware	8.00	Contracted
Water consumption	**Value, m³**	
Water sold as is	16000	Contracted
Freshwater to Platform B	75000	Contracted
Freshwater to 3rd parties	17000	Includes communities
Industrial water to Platform B	2900000	Minimal value
Industrial water to 3rd parties	750000	Minimal value
Water for VIROMET	**1678400**	Includes losses
Industrial Water to VIROMET	922016.368	Max = 1661616
Fresh water to VIROMET	10418.338	Max = 16616

Optimized Criterion:	*Water consumption, m³*	*932435*
Total Water to VIROMET	932434.706	
Water available	**Value, m³**	
Industrial water	739599.632	
Fresh water	6197.662	

Table 4. Minimized consumption of water.

The structure of the water consumption still takes account that signed contracts should be fulfilled. Other consumptions are at the minimal level provided by the restrictions.

Table 5 illustrates the maximization of the VIROMET production, given a limited amount of water available.

Optimized Criterion:	*Maximal production, Euro/yr*	*29260434*
Productions, tons	**Value**	**Remark**
Methanol	71480	Potential
R&D	30	Contracted
Resins	97745	Potential
Plastic ware	50	Contracted
Water consumption	**Value, m³**	**Remark**
Water sold as is	160000	Contracted
Freshwater to Platform B	5000	Contracted
Freshwater to 3rd parties	17000	Includes communities
Industrial water to Platform B	2900000	Minimal value
Industrial water to 3rd parties	750000	Minimal value
Water for VIROMET	1998400	Includes losses
Industrial Water to VIROMET	1978416	Max = 1978416
Fresh water to VIROMET	19784	Max = 19784
Total Water to VIROMET	1998200	
Water still available	**Value, m³**	
Industrial water	0.00	
Fresh water	0.00	

Table 5. Scenario 3: Maximizing production, given the water amount available.

In this case, the scenario includes two levels for already contracted products (for the R&D department and for the Plastic ware department). The production of all other components of the system is arranged so that highest profit possible is attained, all the available water is consumed and all the contracts with 3rd parties, observed. As can be seen, in the end, there is no industrial water or freshwater left, when the production is maximized.

This zero-level availability refers to the fact that the system cannot consume more water than the above amounts, though the adjacent rivers could provide for some extra quantities. But the restrictions were imposed in order to preserve the habitat. The environment could not sustain, in this case, larger water intakes by the water system studied.

Optimized Criterion:	***Maximal production, Euro/yr***	***12850587***
Productions, tons	**Value**	**Remarks**
Methanol	44682	Potential
R&D	30	Contracted
Resins	55471	Potential
Plastic ware	48	Potential
Water consumption	**Value, m³**	**Remarks**
Water sold as is	100000	Contracted
Freshwater to Platform B	90000	Contracted
Freshwater to 3rd parties	20000	Includes communities
Industrial water to Platform B	2000000	A 50000o m³ reduction to provide enough water to communities
Industrial water to 3rd parties	800000	Agreed level, for agricultural uses in the area
Water for VIROMET	1192000	Includes losses
Industrial Water to VIROMET	1180080	Max = 1180080
Fresh water to VIROMET	7499	Max = 7499
Total Water to VIROMET	1187570	
Water still available	**Value, m³**	
Industrial water	0.00	
Fresh water	0.00	

Table 6. Drought year. Optimal production structure.

The scenario includes a drastic reduction of water (20%) for PLATFORM B and a major increase in the amount of water given to communities for agricultural purposes. In this case, the model finds the optimal production profile at VIROMET in order to reach the maximal possible production value, given the water restrictions. The zero-level availability refers, again, to the fact that the system cannot extract more water from the available resources than the above amounts without affecting the environment.

In this case, the set of restrictions is modified to take into account the limited water availability.

Though this is only a potential situation, it becomes clear that the new restrictions may gravely affect, in this scenario, the productions and benefits of one or more of the companies in the VIROMET WMS. Though the above scenario will probably not materialize in the years to come in the focal area, provisions must be made that such situations do not generate conflicts.

The simplest way in allocating scarce resources is that managers (and PAB) convene and add to each flow in the system a priority. The mathematical model should be modified such priority coefficients or weights and this can be easily done. But the use of priorities and allocation keys, even convened and accepted by all water consumers of the system does not solve the problem. Any allocation generates animosity and can lead to conflicts. Some of the consumers could leave the system, making all the management and optimization work pointless.

The solution should be mathematical as well as ethical. If some of the water consumers cannot use (or can use only a part of) this valuable resource for their processes, they cannot generate profit and cannot survive. Adopting a consensus policy and a co-operative approach to sort out the potential conflicts leads to a procedure to share the profits and benefits generated by those companies that consumed water, among all members of the water system. Though the procedure could be thought as unfeasible because it implies total and permanent transparency and frankness from all stakeholders, it works in the Israeli kibbutzim [20]. In order to build trust among all stakeholders, they must be able to verify the accounting registers of all those companies that have used water.

The last scenario presented illustrates the derivation of the optimal value of an eco-efficiency indicator, a new metrics in the focal area.

The criterion gives the minimal value of the m^3 of water consumed per monetary unit of production of the VIROMET WMS. The optimal value of the criterion and the production structure is presented in the Table 7.

Optimized Criterion:	***Minimal water consumed m^3 / 1000 euro production value***	***38.729***
Productions, tons	**Value**	**Remarks**
Methanol	32805	
R&D	268	
Resins	54723	
Plastic ware	34	
Water consumption	**Value, m^3**	**Remarks**

Water sold as is	250000	Contracted
Freshwater to Platform B	90000	Contracted
Freshwater to 3rd parties	20000	Includes communities
Industrial water to Platform B	2900000	Contracted
Industrial water to 3rd parties	30000	Contracted
Water for VIROMET	1872000	Includes losses
Industrial Water to VIROMET	930831	Max = 1853280
Fresh water to VIROMET	18532	Max = 18532
Total Water to VIROMET	949363	
Water still available	**Value, m^3**	
Industrial water	922449	
Fresh water	0.00	

Table 7. Computing an eco-efficiency indicator.

As can be seen, there is still some industrial water available but it cannot be used because the restriction imposed to the drinking water was reached. The model points to a limitation of the system that could cause problems. In order to avoid such circumstances, managers should look to expand the capacity of the fresh water production facility.

By calculating regularly such eco-indicators, the managers can appreciate if the performance of the platform is getting better and make the necessary adjustments.

A large number of similar scenarios and optimization criteria were tested, showing the capabilities of the model that still remains simple and versatile.

7. Forecasting

Knowing what will be the trends in a water system in the near future (3-6 months) is essential for the managers of the companies and consumers included in the VIROMET WMS. They can buy the necessary amounts of reagents, set up plans for maintenance, negotiate future contracts, evaluate the future risks that could hamper their production, etc.

The mathematical model of the system included also a forecasting procedure, also implemented in MICROSOFT EXCEL.

To illustrate the approach, Figure 3 shows the monthly amount of water entering the VIROMET wastewater treatment facility from all consumers connected to it.

First of all, moving average graphs are derived, using 2 values and 4 values in averaging, respectively (both situations are illustrated in Figure 3). It can be seen that going from 2 to 4 value moving averages does not sensibly improve the situation and that still no pattern seem to emerge.

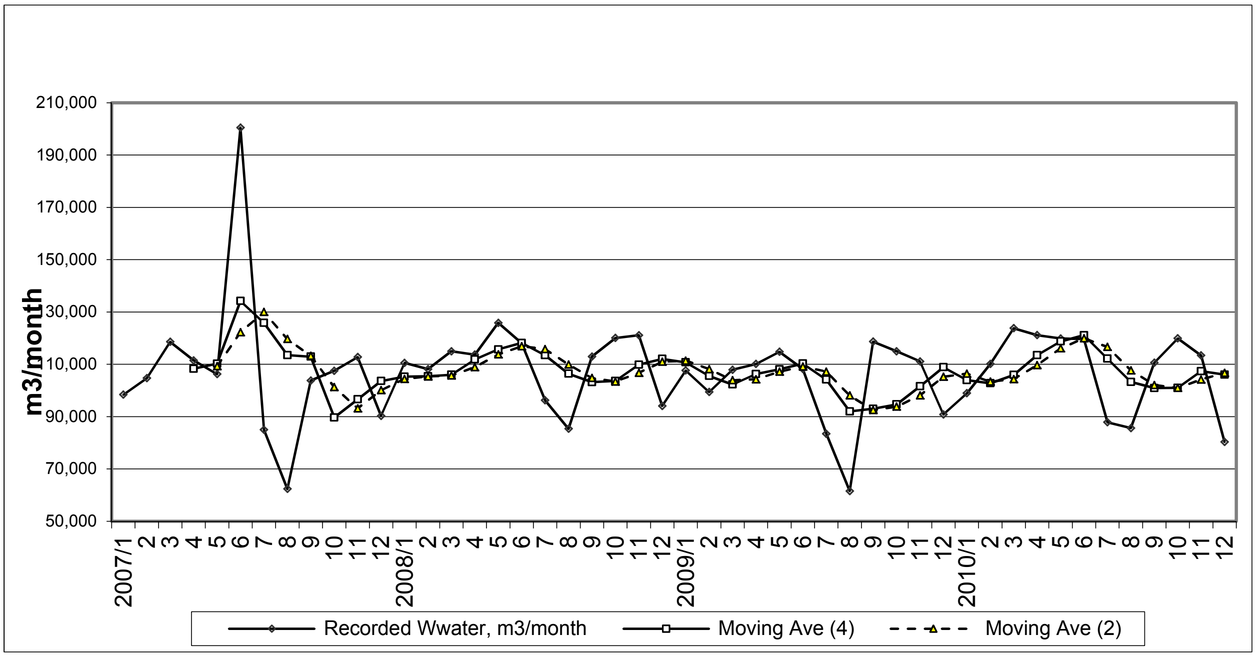

Figure 3. Actual and smoothed variation of wastewater treated in the VIROMET facility.

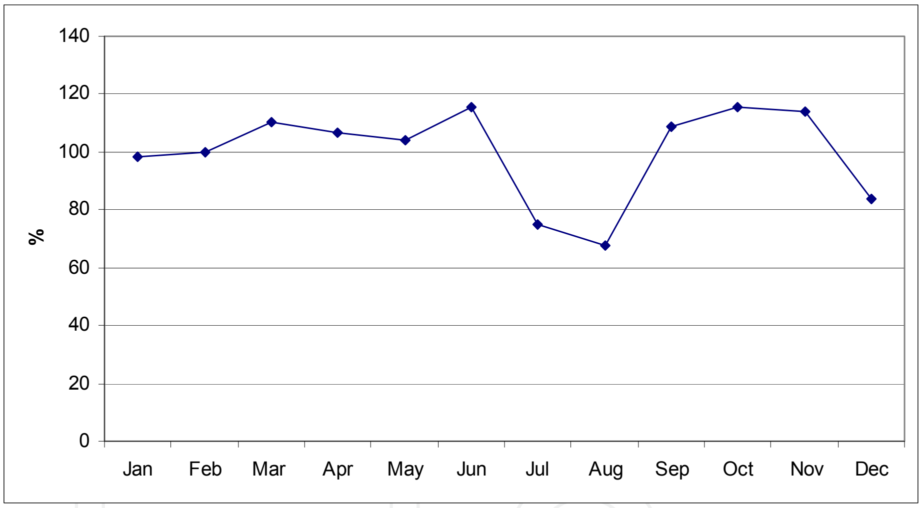

Figure 4. Seasonal Index for the wastewater reaching the treatment facility.

Apparently, there is no pattern governing the graph in Figure 3.

Applying a procedure for calculating a seasonal index for the amount of wastewater [21] leads, nevertheless to a conclusion, illustrated in Figure 4. Data used to infer such an index are taken from the years 2007-2010.

It seems that there is a gap in July and August as well as at the end of the year.

If the pattern stands, July –August or December would be the right periods to carry out revisions, technical repairs, and maintenance of the wastewater treatment plant.

March and October-November are the months when the wastewater facility works well over its annual average.

In order to test the seasonal index, it is used to predict the consumptions in the first half of 2011. Results are presented in Table 8.

Month	Predicted value	Actual value	Absolute deviation	Relative deviation, %
Jan 2011	105,672	114,091.00	-8,419	-7.38
Feb	107,696	113,637.00	-5,941	-5.23
Mar	118,487	124,225.00	-5,738	-4.62
Apr	114,587	121,675.00	-7,088	-5.83
May	112,175	122,339.00	-10,164	-8.31
Jun	124,466	121,953.00	2,513	2.06
Total	683,082	717,920	-34,838	-4.85

Table 8. Predicted and actual values for the wastewater reaching the treatment facility.

Deviations of actual recorded values from predicted values are, in all cases, less than 8.5%. For the entire first half of 2011, the relative error is only 4.85%. The seasonal index calculations are self-learning (additional data can be added at any time, once available, in order to make the index more accurate).

A large number of variables of the VIROMET WMS were subjected to forecasting in order to provide the local managers with useful decision support tools.

8. Conclusions

The study presented a methodology that assess and optimize an expanded system, including multiple water users and offers to local managers simple yet versatile tools to analyze various scenarios for their businesses.

A synthetic outline of the methodology follows:

1. Observe the legal framework governing a river basin but adopt a flexible approach, tailored to the area studied – legislation cannot include all the particular aspects of a given case. Stakeholders' actions should therefore be complementary and implement the general norms in their letter and in their spirit.
2. Organize the task force that will carry out the Project, identify stakeholders, set up a Project Advisory Board; it is important that all major consumers of water in the area are attracted in the Project;
3. Establish communication procedures, encourage transparency, dialogue, identify potential sources of conflict and be prepared to solve such conflicts. An external facilitator could prove essential for such instances since it is presumed that the facilitator has no interests in the area and his judgement will remain fair and objective;

4. Evaluate the existing situations: interactively carry a SWOT and a DPSIR analysis; refer to PAB and local managers to validate the results of these analyses;
5. Identify sources of reducing consumptions (cleaner production options, comparison to BAT, recycling possibilities, etc.);
6. Carry out internal benchmarking and establish the best achieved performance of the water system. Ask managers to identify and replicate the situations that led to that best performance; as a first step in a more elaborated data-mining process, this procedure will lead, in the short time and with practical no investment to sensible improvements;
7. Establish the exact structure and characteristics of the water system to be optimized (components, material balances, water quality analyses);
8. Build up a mathematical model for optimization using MICROSOFT EXCEL software package: interactively establish various relevant criteria, identify, in each case design variables, model parameters, set of restrictions. This operation should be carried out together with local managers and experts, they being the end-users of the model;
9. Test, together with local experts, the validity of the model by analysing as many scenarios as possible, simulate past known situations, examine all the possibilities of the model;
10. Update the key performance indicator system of the system by adding new metrics, e.g., eco-indicators that will assess the trend of the water system toward sustainability; include the new metrics in the strategy metrics operating at the water system level;
11. Help local people convene upon allocation keys for the case the water available is under the threshold needed by the system; establish a procedure for conflict resolution, in case some of the water users will not be able to access all the water they need for their processes; suggested approach: establish a way to distribute the profit accumulated by some of the stakeholders to all the members of the water system, in a transparent and fair manner;
12. Help local managers with other decision support tools, e.g., forecasting. Derive the seasonal index for as many variables in the system as possible, keeping the forecasting model open to include future available data;
13. Test procedures for expanding the mathematical model to include additional consumers.

The main advantages and disadvantages of the methodology and its are summarized below:

- The approach calls for support and participation of all stakeholders, in a given area, using the same water sources; if major water consumers are excluded from the system, the results of the optimization program will be grossly incorrect and generate major risks (e.g., in the situation when the water supplying system is under stress by climatic events);
- The characteristics of a given water system are better known and can be monitored in the long term by local experts so their involvement in the Project is essential. Setting up a Project Advisory Board could be a solution;
- This Project Advisory Board is of great help in assessing the accuracy of the assumptions made by the mathematical analysis, the precision of the set of restrictions

as well as the water allocation keys in cases this resource is scarce (drought, long and heavy winters);

- In case the set of restrictions imposed to some consumers affects their performance and profit, procedures should be in place to give them a fair compensation;
- The optimization model uses the MICROSOFT EXCEL capabilities, therefore it can be easily implemented on most computers;
- The forecasting procedures should be used for short-term planning not only in the case of water consumption but should be extended to all main operations and issues affecting the system and its components (power and fuel consumption, product demand, planning maintenance and revisions, etc.);
- Adding new components to the water system should be done only after evaluating (with the help of the mathematical model presented) the capacity of this water system to sustain new consumers. As an option, all members of the water system could agree to some new allocation rules;
- The parameters of the mathematical model (specific consumptions, restrictions) should be revised via a detailed work of implementing cleaner production and best available techniques options that will lead to reduced water consumptions by each consumer in the water system;
- In order to increase the relevance of the set of results obtained with the mathematical model, consumers should agree to disclose the performances of their internal processes so that they can be included in the optimization criteria. This calls for confidentiality arrangements among all the users of the mathematical model.

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