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*(Small Hydro Action for the Promotion of Efficient Solutions) EC project,*
*co-ordinated by the European Small Hydropower Association (ESHA)*
*under contract TREN/07/FP6EN/S07.74894/038539 agreed in October 2007*
*within the framework of the specific research and technological development programme*
*„Integrating and Strengthening the European Research Area (2002-2006),*
*Sustainable Energy Systems".*

**Janusz Steller**

# FINAL REPORT ON IMP PAN CONTRIBUTION TO THE SHAPES PROJECT

**IMP PAN Rep. 442 / 2010**

**Gdansk, August 2010**

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# Introduction

This report has been prepared within the framework of TREN/07/FP6EN/S07.74894/038539 contract on EC funded project *Small Hydro Action for the Promotion of Efficient Solutions (SHAPES),* agreed in October 2007 between the Consortium of Partners headed by the European Small Hydropower Association (ESHA) and the European Commission. The Consortium involved 10 partners, including the Szewalski Institute of Fluid-Machinery of the Polish Academy of Sciences (IMP PAN).

Due to the AC cost model regulations, the work of IMP PAN co-workers was paid mainly from the means of the Polish Ministry of Science and Higher Education for supporting the IMP PAN statutory activity. Some costs will be probably covered also from the funds earned within the contracts with Polish hydropower plants. Some part of the work was conducted on volunteer basis, mainly by members of the Polish Hydropower Association (TEW).

Following the contract stipulations the IMP PAN was expected to contribute to work packages WP2, WP3, WP4, WP5 and WP7 by the following actions:

1. Contribution to identification of SHP research actors
2. Contribution to the development of a curriculum for SHP on mechanical engineering issues
3. Identification of R&D priorities on mechanical engineering issues for the R&D Agenda
4. Translation of the Layman's Guide on How to Develop a Small Hydropower Plant into Polish
5. Organising the Research Actors Networking Event in Poland
6. Contribution to the identification of potential sites for refurbishing SHP in Poland
7. Identification of best practices on multipurpose plants in Poland

This report comprises basic information on actions 1, 4, 5 and 7 in which the input of IMP PAN was most significant. Observed R&D trends and priorities (action 3) are briefly commented and some other activities linked directly with project objectives are also reported..

# Identification of SHP research actors

Following stipulations with the Work Package 2 leader (*MHyLab Minihydraulics Lab*, Montcherand, Switzerland), the IMP PAN was responsible for identifying the SHP research actors in the following European states: Bulgaria, Czech Republic, Norway, Poland, Romania, Slovakia and Slovenia. The main source of information were internet and available conference proceedings. Traceable reports on research and development activity within the last decade (1998-2008) were initially considered the main criterion. Therefore the data on research & development projects were collected at the same time. Due to significant problems in accessing these data, the criterion of "traceability" was softened later on. Some entities known to have conducted research and development activity in the past have been also included in the data base.

Eventually, 23 research entities have been identified, 5 other entities (mainly manufacturing companies) have been put onto the "reserve" list due to some doubts whether they still continue their previous research and development activities (table 1 and 2).

**Table 1 Small hydro research & development actors as identified by IMP PAN**

| No. | Country | R&D Actor |
|---|---|---|
| 1. | Bulgaria | Technical University of Sofia, Faculty of Power Engineering and Power Machines, Department of Hydroaerodynamics and Hydraulic Machines |
| 2. | Czech Republic | Brno University of Technology, Institute of Power Engineering, Kaplan Department of Hydraulic Machines |
| 3. | Czech Republic | ČKD Blansko Engineering Research Institute |
| 4. | Norway | Norwegian University of Science and Technology, Department of Energy and Process Engineering |
| 5. | Norway | SINTEF Energy Research |
| 6. | Norway | Center for Renewable Energy (Senter For Fornybar Energi) |
| 7. | Norway | TURBINOVA AS |
| 8. | Norway | STATKRAFT |
| 9. | Norway | The Norwegian Water Resources and Energy Directorate (NVE) |
| 10. | Poland | The Szewalski Institute of Fluid-Flow Machinery of the Polish Academy of Sciences |
| 11. | Poland | Institute of Power Engineering, Gdansk Division |
| 12. | Poland | Institute of Power Systems Automation |
| 13. | Poland | Technical University of Gdansk, Chair of Turbomachinery and Fluid Mechanics |
| 14. | Poland | Technical University of Wroclaw, Faculty of Mechanical and Power Engineering, Department of Design Fundametals and Fluid-Flow Machinery |
| 15. | Poland | Technical University of Silesia, Institute of Power Machinery and Equipment, Department of Hydraulic Machinery and Equipment |
| 16. | Poland | CEDI Sp z o.o. |
| 17. | Poland | ZRE Gdańsk |
| 18. | Rumania | "Politehnica" University of Timisoara, Faculty of Mechanical Engineering, Chair of Hydraulic and Pneumatic Systems |
| 19. | Rumania | University "Politehnica" of Bucharest , Power Engineering Faculty, Department of Hydraulics, Hydraulic Machines and Environmental Engineering |
| 20. | Rumania | UCM Resita, Hydraulic Machine Research Department |
| 21. | Rumania | Institute of Hydroelectric Studies and Design S.A. |
| 22. | Slovakia | Slovak University of Technology, Faculty of Mechanical Engineering, Chair of Hydraulic Design |
| 23. | Slovenia | Turboinštitut |

**Table 2 Small hydro research & development actors as identified by IMP PAN (“reserve list”)**

| No. | Country | R&D Actor |
|---|---|---|
| 1. | Czech Republic | MAVEL |
| 2. | Czech Republic | HYDROLINK |
| 3. | Czech Republic | CINK |
| 4. | Poland | Gajek Engineering |
| 5. | Norway | VA Tech AS |

The list of identified research and development projects covers 26 items (table 3, Fig. ). There are no doubts that the list covers only a portion of research activity conducted in the above-mentioned countries within the last decade.

Basically, two reasons for the observed lack of comprehension can be stated:

1. Lack of clear qualification criteria for a research body and research activity
2. Difficult access to information on research activity of most R&D actors.

Both of these problems were indicated properly by Prof. Bogdan Popa in his critical contribution to the SHP Research and Development Actors Network Meeting, held in Gdansk in September 2009. It is clear that they were not quite independent from each other, as the lack of information on true activity of the entity had some influence on qualification problems.

The qualification problems concerned mainly public bodies obliged to collect and order data on hydrology, civil engineering infrastructure and some other hydropower linked items. Generally, it was not quite clear whether statutory research activity of some public entities should have been considered a project. In fact, we avoided including such activity in our contribution to the WP2. The problem could occur also with manufacturers of hydropower equipment developing their new products without decisive innovation. Limited access to information made this problem not so significant.

Insufficient access to the data on research activity was stated right at the beginning, as it appeared that some entities stopped presenting information on their projects in the internet some time ago (e.g. at the beginning of the decade) although we knew perfectly well about their continuous intense activity. Some other entities did never put such an information in the internet although small hydro research and development activity clearly followed from their public mission. Access to the data on the ongoing internal R&D projects of the hydropower equipment manufacturers was almost impossible.

We tried to overcome some of these difficulties by contacting directly persons responsible for research in the identified entities. There were three such attempts:

- the first one - immediately after having recognized the entity;
- the second and third one
  – in course of preparations to the SHP Research Actors Network Meeting.

The first attempt concerned solely countries covered by the IMP PAN survey (see Appendix A). Two other two attempts concerned almost all actors identified in the MHyLab list (see our report on the SHP Research and Development Actors Network Meeting). Response was received only in the first step and only from our Polish colleagues in personal link with the author of this report. Probably, heavy overburdening of the majority of highly qualified specialists is the main reason of their reluctance to respond any inquiries. Some other possible reasons were analysed by Ms Aline Choulot and Prof. Bogdan Popa during the SHP Research and Development Actors Network Meeting in 2009.

It seems now that personal connections, participation in small hydro conferences and seminars should be considered a necessary component of a "bottom-up" strategy of data collection in addition to internet surveys. The other strategy possible could be a "top-down" approach in which all contractors would be required by their sponsors to contribute to a European research project database. These could be feasible in case of projects funded from public means, but not in the case of projects sponsored by industry.

**Table 3 Small hydro research & development projects as identified by IMP PAN**

| No. | Country | R&D Actor | Project name/essence |
|---|---|---|---|
| 1. | Czech Republic | Brno University of Technology, Institute of Power Engineering, Kaplan Department of Hydraulic Machines | Ecologically and economically friendly modern power generation technologies |
| 2. | | | Model tests of turbines intended for large discharges and low heads |
| 3. | Norway | Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering | BEDUIN (BEDre Utforming av Inntak, BEtter Design of INtakes) |
| 4. | Norway | Norwegian University of Science and Technology, Department of Energy and Process Engineering | Sand Erosion in Hydraulic Machinery |
| 5. | | | Unsteady flow in wicket gate and runner |
| 6. | | | Experimental investigation of draft tube flow |
| 7. | | | Experimental and theoretical analysis of inlet flow of a Francis turbine runner |
| 8. | Norway | SINTEF Energy Research | Optimisation of fish habitat and hydropower production in River Surna, Mid-Norway |
| 9. | | | Hydrological Modelling Efforts |
| 10. | Norway | STATKRAFT | HYDROFISH |
| 11. | | | Greenhouse gas emissions from hydropower reservoirs |
| 12. | Poland | The Szewalski Institute of Fluid-Flow Machinery of the Polish Academy of Sciences | CLEANERPAS Centre for Clean and Safe Technologies in Power Engineering |
| 13. | | | R&D study on the methods in design of low head hydraulic propeller turbines |
| 14. | Poland | The Szewalski Institute of Fluid-Flow Machinery of the Polish Academy of Sciences + University of Warmia and Mazury in Olsztyn | Model agricultural power generating complexes as an example of dispersed cogeneration based on local and renewable energy sources |
| 15. | Poland | Technical University of Gdansk, Chair of Turbomachinery and Fluid Mechanics | New methods in design of low head water turbine flow systems |
| 16. | Poland | Technical University of Silesia, Institute of Power Machinery and Equipment, Department of Hydraulic Machinery and Equipment | Analysis of selected performance properties of cross-flow hydraulic turbines |
| 17. | | | Development and investigation of a new concept of cross-flow hydraulic turbine regulation system |
| 18. | Poland | Institute of Electrical Engineering | Innovative low-cost river hydropower plant with a screw turbine |

**Table 3 Small hydro research & development projects as identified by IMP PAN** *(continued)*

| No. | Country | R&D Actor | Project name/essence |
|---|---|---|---|
| 19. | Rumania | "Politehnica" University of Timisoara, Faculty of Mechanical Engineering, Chair of Hydraulic and Pneumatic Systems | Taming the Vortex Rope TAVARO |
| 20. | | | A study on performance reliability of hydro-power equipment |
| 21. | | | Assessment of small hydropower potential. MICROHIDROTURBINE |
| 22. | Rumania | University "Politehnica" of Bucharest , Power Engineering Faculty, Department of Hydraulics, Hydraulic Machines and Environmental Engineering | Assessment of small hydropower potential. MICROHIDROCENTRALE |
| 23. | | | A study on complex utilisation of renewable wind and solar energy sources as well as micro hydropower plants under conditions of a green certificate system |
| 24. | | | Web dedicated SCADA system for hydroelectric power plants |
| 25. | Slovakia | Slovak University of Technology, Faculty of Mechanical Engineering, Chair of Hydraulic Design | Cavitation measurements of axial turbine runners blades using various methods |
| 26. | | | Development of a Francis turbine blade print using a computational approach |
| 27. | | | Increasing specific speed of tubular turbines |

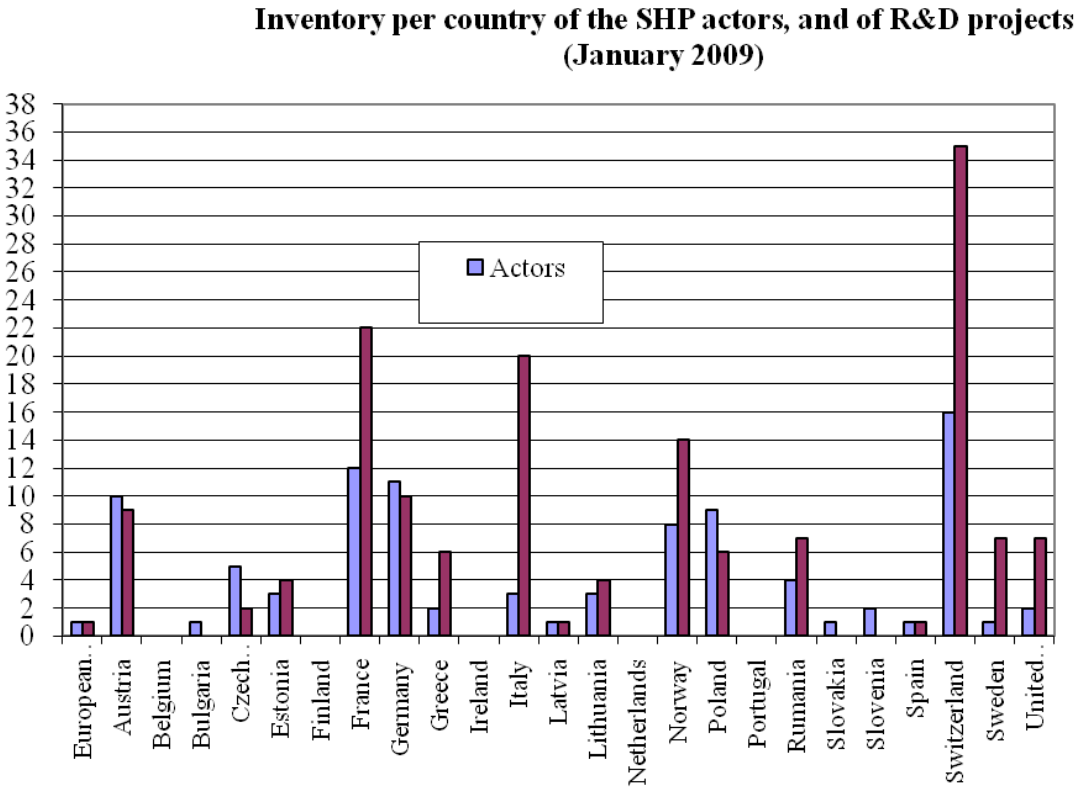


**Fig.1 Statistics of MHyLab inventory of research actors and projects (January 2009 status)**

## Identification of R&D priorities on mechanical engineering issues for the R&D Agenda

Although there was no direct IMP PAN input on this issue, the author of this report has prepared a brief contribution to the SHP Research and Development Actors Network Meeting in Gdansk, summarising recent progress in the design of small hydropower units. The observed trends include:

- intense work on low and very low head machines;
- progress and implementation of variable speed units (also with permanent magnet generators);
- simplifying the techniques of torque transfer from turbine runner to the generator rotor, including integration of both components (e.g. straflo and VLH units etc), or at least avoiding speed multipliers and couplings;
- developing ever more fish-friendly flow systems.

All these trends seem to show still substantial development potential.

It is quite possible that the recent VLH unit design by J.Fonkenell was the major breakthrough in development of low head units within the last few decades. However, continuous progress in modifying some well-known designs (cross-flow turbines, diagonal turbines etc.) is also to be noticed. New application of Archimedean screw is surely a response of technical ingenuity to changing economical conditions for development of low head micro hydropower plants and rising environmental requirements. With favourable policy towards micro energy sources, one may expect attempts to extend the economically justified application range of some advanced units towards lower capacities.

Beyond any doubts there will be also continuous progress in design techniques of some traditional flow systems aimed at further increase of specific speed and efficiency while avoiding cavitation threat. This concerns both the general progress in highly developed entities, but also better access of some small manufacturers to advanced design techniques.

On the other hand side some recently observed trends of research and development efforts supported from the public means may be considered highly controversial. The author of this report remains under strong impression of the effort put in some economically unjustified attempts to use kinetic energy of relatively slow large rivers for electrical energy production purposes. The temptation for such projects is probably due to banning erection of dams allowing for economically reasonable harnessing of existing hydropower potential. There is a feeling that highly qualified hydraulic machinery specialists are not included in the project planning teams.

## Translation of the Layman's Guide on How to Develop a Small Hydropower Plant into Polish

The original version of "Layman's Guide" was written by Celso Penche and published by ESHA in 1998 within the framework of the European Commission DG-TREN (Directorate General for Transport and Energy) ALTENER programme. The first updating and thorough adaptation of the Guidebook to the new situation of the sector was conducted in 2004 within the framework of the *TNSHP (Thematic Network on Small Hydropower)* EC funded project. This was really a heavy and effective effort by a number of partners mentioned in the "Acknowledgements" section. The updated version was published in English (2004), French

(2005), German (2004) and Swedish (2004). In 2006 and 2007 the updated Spanish and Italian versions were published within the framework of SHERPA (*Small Hydro Energy Efficient Promotion Campaign Action*) project. The majority of national versions are not plain translation of the English version of 2004 which is considered the master version. The deviations can be noticed already in the French version. Some new, better quality illustrations, have been added in the Swedish version. Even more modifications can be seen in the Spanish and Italian versions, just to mention information on novel techniques in dam erection. Some errors to be noticed in editions of 2004 and 2005 (references to missing illustrations) have been also removed in SHERPA issues.

As clearly indicated by SHAPES Co-ordinator, also the Polish version was expected not to confine to plain translation from the English master one. This would make really no sense as a substantial part of the Guide refers to the law system of EU and that of some Member States. There are also numerous statistical data to be found in the text - especially in the Appendix to Chapter 9. Almost all of them became out-of-date after 6 six years since the English master version was issued. However, the most important factor was lack of any reference to the New Member States in all previous versions. It was inconceivable to keep this state in the Guide version issued in a New Member State national language.

The draft of the Polish version has been based essentially on translation from the English and French issues. In some detailed questions and especially in case of doubts or poor quality of illustrations, we consulted also the Spanish and Italian versions. Using them as master versions was not possible due to linguistic problems.

After some consideration, we decided to keep the original naming of "Guide" instead of "Handbook" as used in German and Swedish editions. This apparently formal decision is at least partially based on the opinion expressed also by the former ESHA President, Bernhard Pelikan, that developing a small hydropower plant requires a thorough knowledge and skills in numerous fields of natural, technical, economical, judicial and other sciences and fields of human activity. Comprehensive discussion of all of them in a single handbook is a serious and difficult challenge. As members of the Polish Editorial Team really felt the uneven level of the Layman's Guidebook chapters and true lack of comprehension in some of them, we have decided to keep the original naming as used in the English version. Eventually, the title of the Polish issue [1] is "*Jak zbudować małą elektrownię wodną? Przewodnik inwestora"* which may be translated literally as "How to develop a small hydropower plant? An Investor's Guide".

As mentioned, there have been numerous editorial corrections and amendments introduced although care was taken not to disturb the current structure of the Guide. The most significant amendments in comparison to English and French versions are mentioned below. The list has been ordered according to a subjective significance criterion of the author of this report. The authors of respective amendments are indicated in parentheses.

1. The errors noticed in some equations have been removed. Erroneous formulae have been identified in chapter 2 (table 2-5) as well as chapters 5, 6 and 8. Errors in chapters 5, 6 and 8 were simple misprints. However, they could mislead the reader and/or prevent him from making any practical use of the defective formulae (*J.Steller*).
2. Illegible portion of Fig 5-9 in chapter 5 has been replaced by a new figure. Two empirical formulae of unclear origin and units, with probable misprint errors, have been replaced by simplified ones, with empirical coefficients to be read from attached US ACE design plates (*J.Steller, L.Papetti*).

3. A major portion of chapter 1 has been rewritten so as to bring more order in classification of hydropower plants (*A.Henke*)
4. Chapter 3 has been supplemented by information on flow rate measurements using float gauges and some additional information on the current-meter method (*A.Henke*)
5. Chapters 3 and 5 have been supplemented by definitions and recommendations following from Polish regulations on civil engineering works (*J.Steller, K.Trojanowska*). Additionally, the information on penstocks (Chapter 5) has been updated (*P.Pill*).
6. Information on the principle of hydraulic turbine principle of operation, VLH units and hydraulic gravity machines (including Archimedean screw) has been introduced (*J.Steller*). Illustrations in the control system and electrical equipment sections have been supplemented and/or replaced by those of higher quality (*A.Henke, W.Janicki*).
7. Chapter 9 has been substantially amended by adding information on current Polish regulations and administrative procedures (*K.Trojanowska, J.Steller*).
8. The Appendix 9A has been practically completely rewritten. Current information on electrical energy market as well as relevant EU law and policy has been introduced (*J.Steller* with assistance of international advisors)
9. Introductions to chapters 1, 7, 8 and 9 have been thoroughly updated and provided with references to currently valid documents (*J.Steller*).
10. The number of references in bibliography lists to all chapters has been decisively increased. References to numerous hand- and textbook as well as monographs, valid acts of law and political statements have been added (*J.Steller*).

A group of over a dozen of persons was involved in the work (Appendix B). Translation was conducted mainly by Mrs Julitta Jagielska (TEW) and Dr Janusz Steller (IMP PAN). The very first translation of chapters 1, 2 and several sections of chapter 3 was done in 2008 by students of the Technical University of Gdansk. Some parts of the text were translated also by Dr Maciej Kaniecki (IMP PAN).

Most of the editorial work was done by the members of the Editorial Committee. However, invaluable professional input of volunteer external reviewers and advisors is to be acknowledged. Due to substantial input to the current form of chapters we added also some names to the list of authors at the end of each of chapters. There was not much time to contact original authors on this issue, but we considered it unfair to change substantially the published text without taking any public responsibility for such a step.

The author of this report is convinced that a new value has been added again to the already existing document which was already considered the "ESHA bestseller". He has been also informed on numerous occasions that the Polish edition of the Layman's Guide is impatiently awaited by the Polish market. The Polish Association for SHP Development (TRMEW) has already declared its interest in acquiring rights for publishing a printed version and increasing the number of CD ROM copies.

On the other hand side, the author of this report and Chief Editor of the Polish edition of the Layman's Guide at the same time has no doubts that bringing the Guide to even higher standards is needed and that this requires further intense work. The most important needs could be specified as follows:

1. Dividing chapter 6 on electromechanical equipment into two or even three separate ones.

   The section on electrical equipment should be written as a new separate chapter. Much wider information on generators (especially in view of the recent progress in this field) is really needed. Information on electrical safeguards, connection to the grid etc is much too scarce at the moment.

   Information on control and protection systems is also much too scarce. The reader does not learn about the need to optimise double regulated turbines and about the cam curves. And the situation gets even more complicated (not necessarily for the operator) with the advent of variable speed generators. General information on the structure of monitoring and control systems and their tasks is needed. Attention should be paid to various kinds of safeguards (especially runaway related trips). Control and monitoring system problems can form a separate chapter which is probably the best solution. However, discussing control systems together with electrical equipment is also an option.

   The part on mechanical equipment requires further refinement. Amendments introduced in Polish edition (principle of turbine operation, VLH units, hydraulic gravity machines) were needed, but not sufficient. The reader should learn about typical hill diagrams, optimisation of machine operation etc. Information on modern seals and bearings is also needed. The reader is not expected to learn how to design a new turbine, but he should know the principle of its operation, influence of its performance characteristics on his economic effects, and the structural components crucial for its reliability and long-term operation.

2. General revision of the guidebook structure
   and optimisation of information distribution within the text

   At present a lot of information is dispersed in various chapters. While some repetitions are needed to keep the considerations clear and easily conceivable, dispersion of information on the same item poses difficulty both to the reader and to the editors of consecutive versions. This concerns in particular frequent reference to EU legislation and political acts. The relevant portions of the guidebook text get extremely swiftly out of date. Such a situation poses also the editors of consecutive editions in a fairly difficult situation in which they have to choose between the following solutions:

   a) plain translation without bothering about any updates,
   b) removal of the text out-of-date
   c) complete updating of the obsolete text.

   We have selected option (c) for Polish edition which we consider the most fair one. However, in view of the amount of work we were also tempted sometimes to use solution (b). With current experience and thorough knowledge of the guidebook contents, we strongly recommend limiting the number of places requiring such kind of revision in course of preparing every new edition.

   Another problem is a systemic decision on including information referring to local conditions and legislation in the next national issues. This time we limited ourselves to statements informing which part of the text reflects Polish regulations. However, using special font or some other means, could help future editors to decide which part of the text should be translated and which one should be summarised or omitted.

3. Refining the civil engineering material

   This is probably the best part of the Layman's Guide. Some valuable updates on new technologies have been already introduced into the Spanish version. Due to linguistic problems they were only scarcely used in the Polish edition. However, the author of this report is under impression of some excellent presentations during the Network Event and considers further refinement possible.

4. Revision of illustrative material

   Only few new illustrations have been added in the Polish edition. In some cases we reviewed all the previous versions seeking for an illustrations of sufficient quality. However, much more could be done. 6 years after the master version issue there is a lot of additional illustrative material available in digital form.

In the opinion of the author of this report, items (1) and (2) are quite crucial while items (3) and (4) may be considered optional. It is strongly recommended to update the master version in English before starting to work on the next national editions. This will help to keep the consistency of various versions while avoiding unnecessarily repeated effort and loosing valuable input to the previous national editions. Studying in detail all previous national versions, when preparing a new one, becomes practically impossible as they get too numerous.

The above remarks by the author of this report do not change his feeling of satisfaction of having an opportunity to contribute to making ESHA Guidebook available for Polish reader. It is because of his understanding the significance this publication has for a potential European SHP developer that he has found his duty to share his considerations on possible refinements with the SHAPES Project Co-ordinator.

## The SHP Research & Development Actors Networking Event in Poland

The Networking Event, planned originally for 2008, took place eventually in Gdansk in September 2009. Detailed reports on the Event have been prepared both in Polish[1] and English [2]. Copies of all presentations were distributed among Event Participants on a flash disk [3]. Additionally, a copy of Proceedings comprising submitted papers has been recently issued and will be distributed electronically in the beginning of September 2010 [4].

As already explained, our intense efforts to involve a significant number of previously identified research and development actors did not appear successful. The total number of participants was 32. However, good atmosphere of fair discussion on small hydro research and development problems as well as some other SHP sector related problems was created. Beyond any doubts it has been shown that there is a continuous technical progress within the sector and related fields and that this progress is really needed if the sector is to keep its position on the market while keeping to the increased environmental constraints. The Event Network Report, Proceedings and copies of MS Power Point presentations should be considered a highly stimulating material for further research and development activity on small hydro problems.

[1] Steller J. Kaniecki M.: *Sprawozdanie ze Spotkania Sieci Wykonawców Prac Badawczo-Rozwojowych na Rzecz Małej Energetyki Wodnej*, Opr. IMP PAN nr 499/2009

## Identification of best practices on multipurpose plants in Poland

Poland is a country of numerous multipurpose plants. Flood protection and participation in other water management tasks has been the main reason of erecting the prevailing majority of water reservoirs within the last 80 years. Only in single cases the sequence has been the opposite and even then water management remains usually one of essential tasks according to the water-legal consent (concession to use water for hydropower purposes). In few cases additional tasks, e.g. abstraction of drinking water, have been added after long time of reservoir exploitation. This is the case of Straszyn HPP reservoir, visited by the participants of Networking Event on September 11th, 2009. Straszyn Lake is today one of main sources of drinking water for the town of Gdansk. Water is delivered to Gdansk by *Saur Neptun Gdansk SA*, a part of *SAUR* French Capital Group.

**Fig.2 Straszyn Lake at sunset (Photograph by Maciej Kaniecki).**
**The lake is the lowest reservoir in the part of Radunia HPP Cascade planned for swell operation. It is also a significant component of flood protection system and a source of drinking water for the town of Gdansk**

In our contribution to the Work Package 5 we have presented two much less common schemes (Appendix C). In both of them hydraulic energy lost in technological processes is recovered. The first one concerns recovery of hydraulic energy in a Municipal Heating Plant in Lomza (North Eastern Poland). The installation is a result of a research and development project funded by the Polish Committee on Scientific Research and has been described in our contribution to Hidroenergia'98 [5]. The second one concerns recovery of hydraulic energy of water at the cooling system outlet of a 500 MW Thermal Power Plant close to Cracow.

## Other activities

SHAPES means have been used to support participation of IMP PAN staff in some small hydro related conferences and meetings, including Hidroenergia'2008 and 2010, HYDRO'2008 and 2009, as well as *SHAPES Seminar on Multipurpose Plants* in June 2009. The support was limited to personnel involved in the work for the project and mentioned in the contract.

A small portion of SHAPES means has been used also to support educational activity on small hydro in Poland. Travel costs of Mr Adam Henke, delivering lectures at the "ABC of small hydro" series of schoolings for potential SHP investors have been covered from this source. The schoolings were organised by the Polish Association for SHP Development (TRMEW) at the following sites and dates

1) Radzików (Mazovian Vioivodship, March 13 – 15th, 2008)

2) Cracow (September 18–20th, 2008)

3) Jastrzębia Góra (Pomeranian Voivodship, March 19 – 21st, 2009)

4) Jastrzębia Góra (Pomeranian Voivodship, May 14 – 16th, 2009)

5) Oleśnica (September 25-27th, 2009)

6) Warsaw (March 5 – 7th, 2010)

## List of deliverables

1. *Jak zbudować małą elektrownię wodną? Przewodnik inwestora*, ESHA, Bruksela, 2010
2. Steller J., Kaniecki M.: *Small Hydro Research & Development Actors Network Meeting - Final Report*, IMP PAN Rep. 437/2010
3. *SHAPES R&D Actors Network Meeting.* Presentations and Photographs, IMP PAN, Gdansk, September 11th 2009, Flash Disk
4. *SHAPES R&D Actors Network Meeting. Proceedings*. The Szewalski Institute of Fluid-Flow Machinery of the Polish Academy of Sciences, Gdansk, August 2010
5. Steller J., Adamkowski A., Stankiewicz Z., Łojek A., Rduch J., Zarzycki M.: *Pumps as turbines for hydraulic energy recovery and small hydropower purposes in Poland.* HIDROENERGIA'2008, Bled (Slovenia), June 11-13th, 2008, Session 5A, CD-ROM

# APPENDIX A

## A copy of typical inquiry on small hydro R&D projects

**Od:** Janusz Steller [steller@imp.gda.pl]
**Wysłano:** 13 stycznia 2009 16:17
**Do:** pochyly@fme.vutbr.cz
**DW:** Grzegorz Gołębiewski; Maciej Kaniecki; haban@fme.vutbr.cz
**Temat:** SHAPES project

Dear Professor Pochyly,

Since several years I have the pleasure of representing my institute in the European Small Hydropower Association (ESHA, www.esha.be ), an institution representing the interests of the small hydropower sector at the EU level. ESHA co-ordinates also several projects aimed at promotion of small hydro power, collection of data on the sector condition resources etc.

Now, I'm writing to you this message because of my involvement in Workpackage 2 of the SHAPES project. SHAPES is an acronym coming from Small Hydro Action for the Promotion of Efficient Solutions. The scope and purpose of the work package are briefly summarized below. Further information on the project can be found at the ESHA website. I'll be really highly obliged to you if you or any of your co-workers could advise me on:

1. most significant research bodies active in the SHP sector within the Czech Republic (an Slovakia if possible)
2. research projects oriented on SHP development and conducted at your place (or possibly at some other place in your country) within this decade (since 2000)
3. any other person/establishment capable to provide me with such an information

The information I should provide on the projects covers the following data:

- Country
- Institution name
- Name of the project
- Key words
- Objective
- Type of project (research / demonstration)
- Regional / National / International funding
- Project period
- Investments
- Comments on the sucess/ unsucess
- Ready for the market (already on the market, at short - 1 year- /mid - 5 years- /long ->10 years- term)
- Results access (public, confidential, free, royalties, …)
- Any openings to other projects?

However, I'll be most grateful for any information you could provide to me.

With kind regards

Janusz Steller

P.S.: I hope very much to be able to attend the IAHR International Meeting of the Work Group on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems organized by you in October this year. I learnt about the event when studying your website. I'll be more than glad to visit Brno after 20 years. We kept good contacts with Prof. P.Fleischner and some colleagues from Olomouc at this time.

# APPENDIX B

## List of persons having contributed to the Polish version of Layman's Guide

### Editorial Team

1. Janusz Steller (IMP PAN) – Editor in Chief
2. Adam Henke (IMP PAN)
3. Julitta Jagielska (TEW)
4. Maciej Kaniecki (IMP PAN)
5. Katarzyna Trojanowska (TEW)

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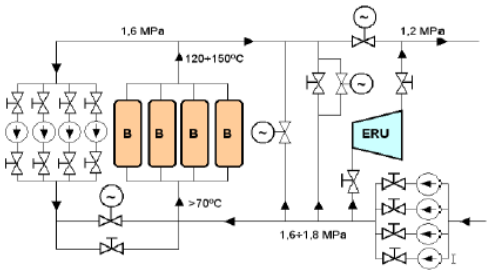
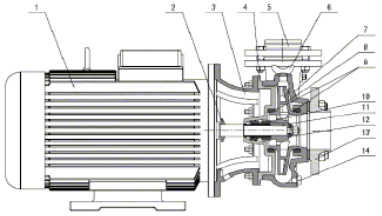
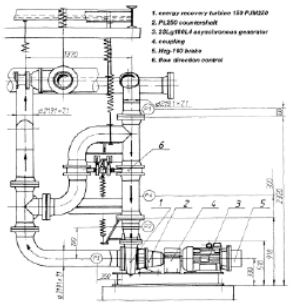
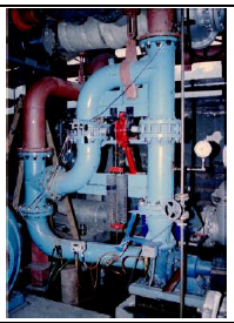
7. Mariusz Lewandowski (IMP PAN, TEW)
8. Stanisław Lewandowski (TEW)
9. Paweł Pill (KWH Sp. z O.O.)
10. Bogusław Kuba Puchowski (TRMEW)
11. Edyta Zalewska (KWH Sp. z O.O.)

### International Advisors

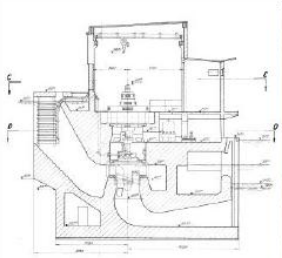
12. Luigi Papetti (*Studio Frosio*)
13. Bernhard Pelikan (ESHA, *University of Natural Resources*, Vienna)
14. inż. Ghislain Weisrock (*France Hydro-Électricité, Electrabel France*)

# APPENDIX C

## Multipurpose scheme cards submitted to the WP5 leader

| | |
|---|---|
| **Existing infrastructure** | **"Cold-mixing" by-pass of the boiler block with 400-600 kPa pressure difference** |
| **Powerplant name** | **Hydraulic energy recovery unit in Lomza Municipal Heating Plant** |
| **Location** | **Lomza Municipal Heating Plant (North-Eastern Poland)** |
| **Starting up year** | **1997** |
| **Site description** | Due to technological reasons the boiler block supplies water with temperature over 120 deg C - much too high as for the needs of the municipal heating network. Therefore unheated water has to be mixed with that supplied from the boiler system. The boiler block by-pass conduit with a throttling valve was originally used for this purpose. In 1997 this task was taken over by an energy recovery installation with 250PJM150 centrifugal pump unit of LFP (Leszczynska Fabryka Pomp, Poland) manufacture. Precautions were taken in order to divert smoothly water stream to a bypass conduit in case a shut-down of the unit is needed. Throttling orifice was used to take care of keeping the discharge constant.<br>  <br>Fig.1<br>  <br>Fig.2<br>  <br>Fig.3<br>  <br>Photo 1<br>  <br>Photo 2<br>Fig.1: Simplified schematic of the heating plant hydraulic circuit: B – Boiler; ERU – Energy Recovery Unit, Fig.2: PJM centrifugal pump unit as used for energy recovery purposes, Fig.3: Assembly drawing of the energy recovery installation, Photo 1 and 2: General view of the installation during commissioning |
| **Comments** | The installation was developed under the research project no. 9 0412 9101 of the Polish Committee on Scientific Research (contract no. 580/91). Erection and commissioning costs were covered by the heating plant operator. The installation was in operation since the end of March 1997 till mid 2005 when the control system code was lost during replacement of the memory supporting cell. Repeated coding of the control unit and recommissioning tests were considered too expensive in view of planned removal of the "cold-mixing" need after the general plant rehabilitation. Nevertheless, the plant operator has expressed his satisfaction with 338 MWh of electrical energy recovered during the operation period. |
| **Discharge** | 0.092 $m^3/s$ |
| **Difference in levels** | 30.5 m |
| **Electrical output** | 20 kW |
| **Electrical production** | 39 760 kWh/year |
| **Investment** | no reliable data available due to the method of funding |
| **Involved enterprises** | MPEC Lomza, IMP PAN, LFP (Leszno Pump Manufacturers), Governor Ltd. |
| **Operator** | Municipal Heating Enterprise Lomza (MPEC Lomza) |
| **Figure and Photo sources** | Fig.2 - LFP website, all others - IMP PAN |

**Notice**: 40-60 kPa instead of 400-600 kPa pressure difference was erroneously shown in the card sent to Ms Aline Choulot. This error has been detected only when preparing the present report.

| | |
|---|---|
| **Existing infrastructure** | **cooling water outlet from the 500 MW Skawina Thermal Power Plant** |
| **Powerplant name** | **Skawina** |
| **Location** | **Skawinka river coast, close to its estuary to Vistula at the outskirts of Cracow** |
| **Starting up year** | **1959** |
| **Site description** | The hydropower plant (HPP) was planned together with the thermal one (ThPP). The ThPP uses cooling water taken from Laczany Channel which by-passes a 20 km long segment of Vistula and serves also navigation purposes. The used water is delivered to HPP with two concrete channels. The final portion of the channels is open with side walls used as spillways. After leaving the HPP water is discharged through a 30 m long tailrace channel to Skawinka river. The plant is equipped with a single hydraulic unit (Ganz Mavag Kaplan turbine and an AEG generator). Due to high temperature of water (over 30 deg C) and severe pollution of Vistula the turbine is subject to joint cavitation and corrosion threat.<br>    <br>Fig 1 Photo 1 Photo2<br>   <br>Photo 3 Photo 4<br>Fig.1 Longitudinal section of the Skawina HPP, Photo 1: Machine hall, Photo 2: Power transformers, Photo 3: Delivery channels, Photo 4: Powerhouse during turbine overhaul |
| **Comments** | Planning energy recovery together with a major industrial installation is always a proper strategy. Nevertheless, selecting an outlay with a single unit was not the optimum solution, contributing probably to insuffcient maintenance and rather poor technical condition of the unit after years of operation. The turbine is situated too high as the tailrace channel shows still substantial slope and erection of a low head installation at the outlet to Skawinka river was taken into consideration some time ago. Due to green certificate and green energy quota system in Poland, the owner may be interested in a much more promising opportunity of using substantial head at the Laczany Channel outlet. |
| **Discharge** | 23,3 $m^3/s$ |
| **Difference in levels** | 8,1 m |
| **Electrical output** | 1560 kW |
| **Electrical production** | 6390 000 kWh/year |
| **Investment** | no data available |
| **Involved enterprises** | Skawina Thermal Power Plant, HYDROPROJEKT, Ganz Mavag, AEG |
| **Operator** | Skawina Thermal Power Plant |
| **Figure and photo sources** | Fig.1 - Skawina ThPP resources, Photos 1, 2&4 - Stanislaw Lewandowski & Emil Ostajewski, 3 - IMP PAN |