SEVENTH FRAMEWORK PROGRAMME

THEME [SP1-JTI-FCH.2010.5.1]
[Development of a Framework for Technology Monitoring and Assessments (TMA)]

Grant agreement for: Article 171 of the Treaty*

D1.3- "Final Report"

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Content

I. TEMONAS Project Summary

TEMONAS is the acronym for TEchnology MONitoring and ASsessment. This Project Title is a direct reference to the call topic theme and describes an integrated methodology and IT-tool enabling the evaluation of the technology status of hydrogen and fuel cell technologies as managed by the FCH-JU and its major competitive and incumbent opponents. Guiding principle of TEMONAS is to enable objectified and transparent evaluation of technology status per se, in comparison with other technologies, or monitoring the respective progress of the development of the technology. These functions have been realized in an integrated IT-tool, specifically tailored for the needs of the FCH-JU and also called TEMONAS although as a solution name TEMONAS stands for TEchnology MONitoring and Analysis System, the reasons for this deviation will be given in a later section of this report.

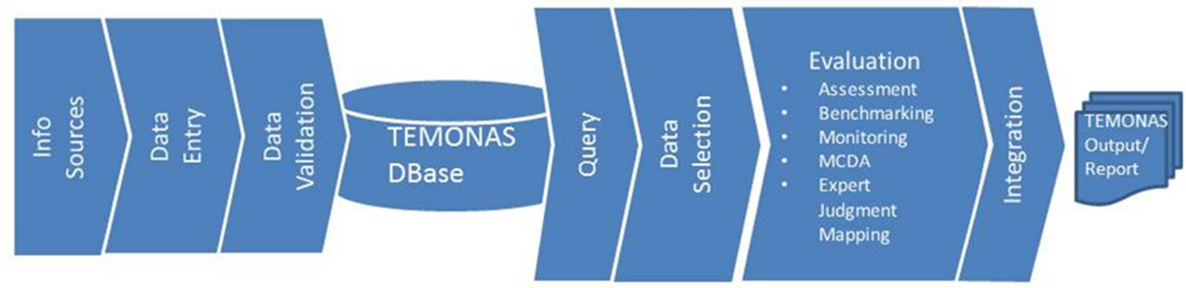


Fig. 1: Simplified Flow Chart of the TEMONAS Functionality

TEMONAS uses state-of-the-art database technology enabling secure multi-user operations. Its range of functions includes data entry with corresponding quality monitoring and validation routines, data selection methodologies, evaluation methodologies including assessment and benchmarking which can be used to develop complex multi-criteria decision aid aggregated results as well as monitoring the development of such metrics over time.

The routines can be customized per user or user group and the respective user group privileges. Such evaluations can then also be stored for later reference and, of course, be plotted and the result data exported in various formats.

Complete functional logging within the data base tool ensures traceability of all inputs and outputs.

TEMONAS was realized by consortium under the coordination of CLIMT GmbH comprising a major research organization as well as sector specialized consulting firms and a software development partner. The project was completed in 21 months and is now in use by the FCH-JU.

II. Final report objectives

The TEMONAS project owed its initial design to the major items listed in the call text of the call theme SP1-JTI-FCH.2010.5.1 development of a framework for technology monitoring and assessments (TMA) (*FCH-JU, 2010*).

In the call document the main rationale for requiring such a tool was given as follows:
"The development of an advanced TMA tool will enable the FCH-JU to obtain an accurate assessment of progress both towards its objectives and its position within the global field of energy technologies. This implies both monitoring of results of the work funded by the FCH-JU program and projects funded by other parties such as national programs as far a state that is made available by the owners. These results can then be compared to each other as well as against the program targets to assess progress of the program and the technology. However, from a more strategic point a few, monitoring competing and emerging technologies and the progress is necessary for timely responses by the FCH-JU" (*FCH-JU, 2010).*

As the funding rules for work under the FCH-JU required the Consortium to provide its own contribution to the project costs the group decided to expand the high level specification of the solution to be designed in more broad fashion in order to have a product that would also address the needs of other funding/financing institutions but also be of use for research consortia, technology laboratories or industry.

The present final report thus aims in the first section to introduce both the TEMONAS project and its achievements, but also provide the respective background regarding the scientific sector of technology management tools. The second section will provide the overview of the functionality and the key structural elements used in building the TEMONAS solution in this specific form as used by the FCH-JU program office.

III. Glossary and abbreviations used in this document

II. 1. TEMONAS specific terminology and abbreviations

TRL	Technology Readiness Level (NASA)
RCS	Regulations, Codes and Standards
IT	Information Technology
RTD	Research and Technology Development
CS	Name of the Middleware and related computer programs in the TEMONAS solution
MCDA	Multi-Criteria Decision Aid
TMA	Technology Monitoring and Assessment
(D)QM	(Data) Quality Management
SOTA	State-of-the-Art
MACBETH	Measuring Attractiveness by Categorical Based Evaluation TecHnique
xRLs	(various) Readiness Levels
MRL	Manufacturing Readiness Level (NASA); also used for : Market Readiness Level
FRL	Framework Readiness Level
IRL	Industry Readiness Level
PCL	Policy Congruence Level
CRL	Commercialization Readiness Level
RO	Research Object

II. 2. Fuel cell related terminology and abbreviations used throughout this document

FC	Fuel Cell
PEM	Polymer Electrolyte Membrane also Proton Exchange Membrane
AFC	Alkaline Fuel Cell
PEM FC	Fuel Cell using a PEM
DMFC	Direct Methanol Fuel Cell
PAFC	Phosphoric Acid Fuel Cell
MCFC	Molten Carbonate Fuel Cell
SOFC	Solid Oxide Fuel Cell
IU-diagram	Current Voltage diagram, typically showing the current density per unit area on the abscissa and the corresponding voltage on the ordinate axis
ASR	Area Specific Resistance (Ohm/cm^2) calculated from the IU diagram
CH2	Compressed Hydrogen
LH2	Liquid(Liquefied) Hydrogen
HT-PEM	High Temperature PEM
IT SOFC	Intermediate Temperature SOFC

II. 3. Competing technology related terminology and abbreviations

FTP75	Federal test Procedure no. 75 (simulated street driving emission test cycle for passenger cars valid in the US and a variety of other countries)
NEUDC / NEDC	New European (Urban) Driving Cycle, the European counterpart to the FTP75
ECE R49	weighted multi-modal engine test for Heavy Duty engines, for emission certification
ICE	Internal Combustion Engine
CNG	Compressed Natural Gas

II. 4. Other terminology and abbreviations

FCH-JU	Fuel Cell and Hydrogen Joint Undertaking
PO	Program Office
BiC	Best in Class (Benchmarking)
BAT	Best Available Technology (Benchmarking)
US	United States (of America)
DoE	Department of Energy
DoD	Department of Defense
METI	Ministry of Economy Trade and Industry (Japan)
NEDO	NEW Energy and Industrial technology Development Organization (Japan)
AA	Application Area (definition used by the FCH-JU)
DoW	Description of Work (Annex to a Grant Agreement of the FCH-JU)
MAIP	Multi Annual Implementation Plan (Key working document of the FCH-JU)
AIP	Annual Implementation Plan (Key working document of the FCH-JU, derived from the MAIP)
ISBN	International Standard Book Number
ISSN	International Standard Serial Number, the ISBN equivalent for periodicals both in print and electronic format
SME	Small and Medium Enterprise
NASA	National Aeronautic and Space Administration (US)
DTC	Design to Cost

IV. Introduction

Background and state-of-the art

The Joint Undertaking for Fuel Cells and Hydrogen (FCH-JU) is a large-scale cooperative research venture involving an industry group and currently representing more than 60 industrial corporations, a research association of about 60 institutional members and the European commission who will jointly invest nearly €1 billion into accelerating the commercialization of fuel cell and hydrogen technologies (*EC, 2008*). The starting point sent targets were developed by European technology platform in a bottom-up approach resulting in three key documents i.e. strategic research agenda, deployment strategy and an implementation plan status 2006 (*HFP 2003, 2005 and 2007*). The scope of the implementation plan covered a 7 billion euro program; however, due to European Commission cash contribution, which was assumed to be around EUR 1 Bio. for the planning period, ending up at just under €500 million, choices in the focus of research, technology development and demonstration had to be made once the exact funding became clear (*FCH-JU 2008*).

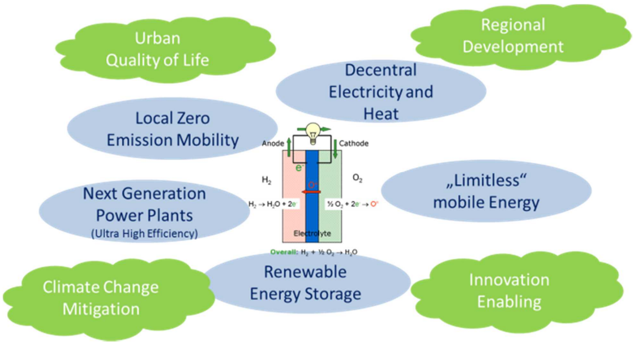


Fig. 2 a/b: Promise of a new technology, e.g. Hydrogen and Fuel Cells and expectations related to those promises *(Wancura, 2013a,b)*

To understand the complexities of such program design decisions one needs to look back to the origins of the FCH-JU. This is an organization to run a Joint Technology Initiative (JTI), a special vehicle for cooperative research created in order to bring back industry as major partners in European research projects where their participation had been dwindling during the past framework programs. In addition, hydrogen had been seen and is seen again as an important potential technology for solving variety of social politically challenges off the future using new technology as change agent.

However, this represents a classic case of a new technology offering tremendous potential in fairly stable market and technology regimes. In retrospective, one could argue, as has been done e.g. by Bakker and Budde (*Bakker, 2012*) that the hydrogen and fuel cell solution had become part of a technological hype, in which expectations about a new technology are continuously inflated in a self-supporting and actually accelerating social system, a process sometimes referred to using the so-called Gartner Hype Cycle originally introduced by Fenn and Raskino *(Fenn, 2008*).

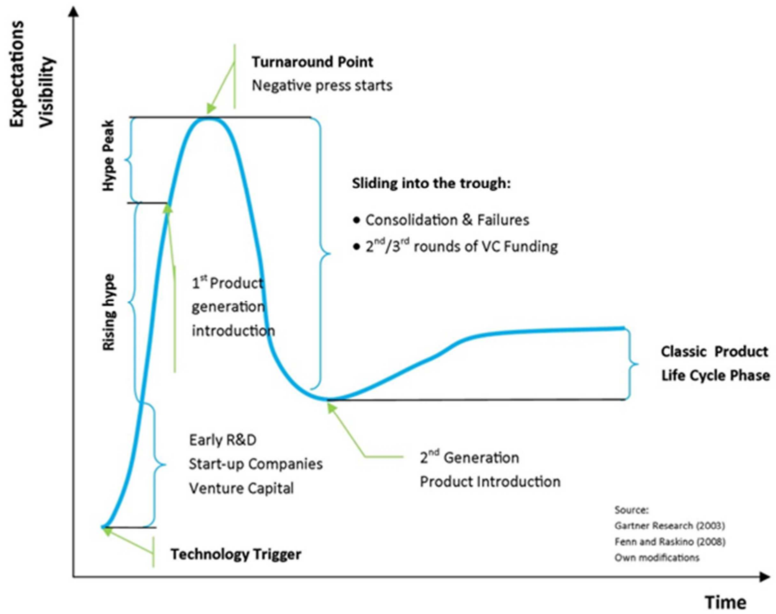


Fig.3: The Gartner Hype Cycle (after Fenn and Raskino, 2008)

In such a climate all participants have specific individual and organizational expectations regarding a technology which is jointly seen as critical for the future. Research into the organizational dynamics and success factors of cooperative research ventures shows that in order for cooperative ventures to be successful, the information sharing must be open. (*Branstetter 2002*, *Sakakibara 2003*). As these earlier publications show, involving partners that are direct competitors in the same target technology and application may not be conducive to create such an open climate as information asymmetries may be seen as critical strategic assets. In addition, involvement of public stakeholders mainly in the form of funding agencies can further compound the asymmetries. In such cases the public party often is at a disadvantage regarding access to detailed information regarding the performance of a technology, but needs to insist on the respect for principles of public accountability dictating transparency and openness about the process of any selection.

One way to unite these sometimes diverging principles is to agree on technology roadmaps. Technology roadmaps are an important element of the so-called scientific management culture first introduced into the public management domain in the USA e.g. by NASA for their space program administrations or in the department of defense during the time of Robert McNamara (Grattan, 2006) and later broadly applied to strategic technology fields in the industry government programs of MITI in Japan (e.g. *Kaneda, 2001*; *DoD 2005, 2011*).

Another example of such scientific approaches is the generation of readiness levels created by NASA as risk management tools. The most prominent of these readiness levels is the technology readiness level TRL, which has seen broad use by other sectors outside space program management or aerospace and has become more or less generally accepted definition norm for technology maturity (.*Heslop, 2001 Graettinger, 2002; ; Nolte, 2003 Dion-Schwarz, 2005; Moon, 2005)*

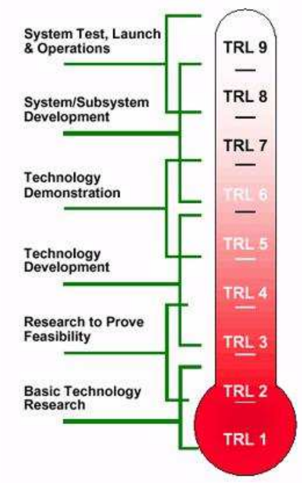


Fig. 4: The TRL Scale as developed by NASA (NASA)

The concept has been expanded over the years to also address other risk fields such as manufacturing readiness or systems integration readiness, and even commercialization readiness, etc. (*Kennedy, 2006; Sauser, 2006; Bilbro, 2009, Volkert, 2009, USC – CTC, 2007, Paun,2011, Dent,2011*).

Although the readiness levels may represent an attractive form of managing certain project categories, their combination has come under some scientific debate more recently (*Kujawski, 2010*) and they represent but one attribute of a technology roadmap, which, of course, needs to further in depth and width.

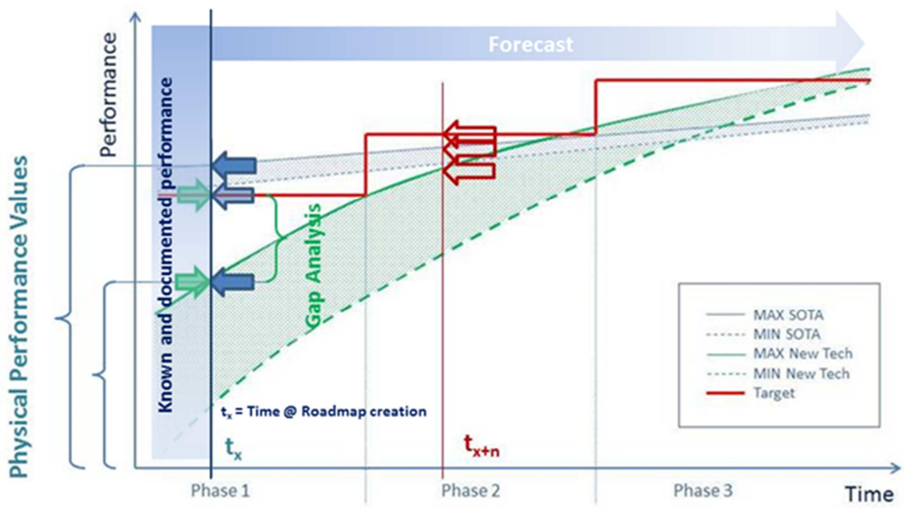


Fig. 5: Idealized Technology Roadmap

In an ideal case such a roadmap is designed by projecting future performances of a given new technology based on past but state-of-the-art known performance. These performances are then compared to the trajectory for the existing or incumbent technology and its performance thereby allowing the formulation of quantitative and qualitative targets. (MOD, *Zernial 2007*)The program design now needs to address the identified gaps between such target performance and actual performance of the new technology. It will typically do so by publishing the targets and inviting scientific and industrial consortia to propose pathways towards reducing or eliminating the gap, and subsequently selecting individual projects addressing one or more dimensions using different technology approaches to achieve a solution. At the predefined milestone dates the performance of the new technology can then be compared to the planning assumptions and targets and management decisions can be made regarding the continuation of both individual projects and the complete program.

On a broad level this process is similar to Gateway Management or Stage Gate Processes employed e.g. in the automotive industry for product development (*Peters, 2010*) In the case of the FCH-JU the stage gate concept is reflected in the midterm review of individual projects which formally represents a continuation/discontinuation decision point for each project as well as a programme level review already listed in the regulation on establishing the FCH-JU (*EC 2008, 2011*). A number of deviations between purely industrial product development and such a cooperative research venture do, however, exist. They are mainly due to the fact that cooperative research ventures (i) operate at very early stages with high levels of uncertainty, where learning from failures might still represent an important contribution and (ii) typically have more than one decision-maker, in particular since the decision is made by officers of the funding agency requiring an impartial and transparent process thus often relying on external expert reviewers (peer review) who thus exert significant influence on the decision.

Another complication comes from the fact that in today's advanced technology world it is quite unlikely that a new technology or its variant will actually outperform existing technology in every aspect. It is much more likely that the technology may e.g. offer better performance for example in environmental aspects, but may actually be more expensive to own or operate.

Decision making thus requires the ability to make broad assessments incorporating a multitude of performance or attribute dimensions. This so-called multi-criteria decision aid has a long tradition in complex project decisions such as location of nuclear plants. While the literature on such Multi-Criteria Decision Aid tool is quite abundant and lists methodologies such as MACBETH method (*Bana e Costa, 2005*), UTA method (*Siskos, 2005*), the Analytic Hierarchy Process (*Saaty, 2005*) and its variants, outranking methods such as ELECTRE by Bernard Roy et al. at LAMSADE (*Roy, 1990*) and PROMETHEE (*J. Brans, 2005*). Our partner CEA –LITEN collaborated with the CNRS LAMSADE laboratory (Laboratoire d’Analyse et Modélisation de Systèmes pour l’Aide à la Décision) of University Paris-Dauphine in an earlier project. LAMSADE is known as one of the world most famous laboratories in the field of Decision Aid and Operational Research and published hundreds of papers in this field.

The objective of the collaboration between CEA and LAMSADE laboratory has been to identify an appropriate MCDA methodology. After a deep review of the numerous types of existing MCDA methodologies and tools, the LAMSADE experts recommended the use of the MACBETH method whose theoretical description can be found in (*Bana e Costa, 2005*); this method has been applied successfully in numerous other fields of application, such as quality index development for energy companies, strategic town planning, credit scoring, portfolio management (*Bana Consulting*). In collaboration with LAMSADE laboratory, the MACBETH approach had been successfully implemented and validated within STORHY project (*Montignac, 2007, 2009*).

Relying on this positive experience the MACBETH approach has been implemented by CEA in the frame of a French research project related to SOFC performance evaluation, conducting a multi-criteria evaluation of the performance of SOFC systems in comparison with other CHP technologies. The multi-criteria decision aid was thus decided to be using the MACBETH methodology as (i) this evaluation method takes explicit advantage of the considerable data gathering that is made in R&D projects, (ii) the mathematical procedures for criteria modelling and aggregation are clear and transparent, (iii) the use of “acceptable” and “satisfying” reference thresholds has been identified as a useful and understandable way to measure quantitative and qualitative performance as well as for measuring remaining R&D efforts, (iv) and the owners of an already existing software application were willing to join the consortium to work on an integrated solution.

A general problem occurs when working in very early stages of technology development work or trying to monitor emerging technologies or – as was required by the specifications of the call – ascribe a relative ranking of “proximity-to-commercialization”. There the main issue is that there is insufficient data for proper algorithm based outputs, either due to the fact that serious development work has just started and it will take years before a sufficient amount of results are published in the open literature to enable broader conclusions or because the data is too divergent to draw any conclusion.

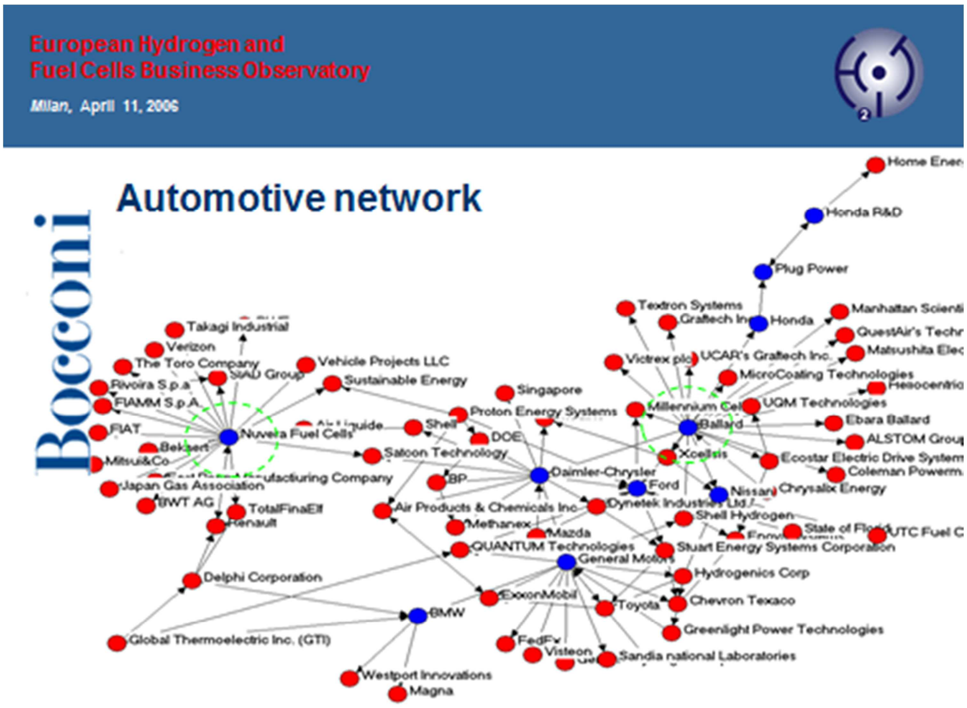


Fig. 6: Social Network Analysis (SNA) as an actor network of the Fuel Cell & Hydrogen related automotive industry in 2006 (Source: Pogutz, 2006)

Based on work apparently co-originating in France in close collaboration with the UK and Netherlands (*Callon, 1986*) and in the USA (*Berkowitz, 1982*) on structural analysis, actor networks and co-word analysis, later work by various researchers (Wasserman, 1994; Valente, 1995; Jackson, 2003; Freeman 2006) while at the same time at Bocconi University Pogutz (*Pogutz, 2006*) demonstrated social network analysis using data from the fuel cell and hydrogen community. In 2010 also to a specialized company using SNA for technology trend monitoring (Quid, Inc.) was started in the USA. However, preliminary assessment lead to the conclusion that using such a tool requires a staff beyond the possibilities of the FCH-JU and thus was –for the time being – not followed up further.

Some industrial technology leaders (i.e. Bob Galvin of Motorola quoted in *Zernial, 2007 p.113*) thus advocate using expert input in developing technology roadmaps. Again, the issue may be the size of the new technology community and the related lack of experts without conflicts of interests. Furthermore, expert input tends to be in the form of reports or presentations always formatted along the preferences of the individual experts very often rendering those input difficult, if not impossible, to compare. On the other hand, it is a broadly observed phenomenon that innovations do not succeed based only on their technical/technological quality (among others *Cooper, 1999; Albetti, 2000; Geroski, 2001, Amara 2004*), but also a broader “fitting” to a variety of factors (Aasrud, 2010). Thus, considerable effort has been expended, for example, to study the so-called NTB (non-technical barriers) to innovation, not least with significant involvement of the European Commission institutions (e.g. *Hollanders, 2008; Reinstaller, 2010*); therefore, a base for a new approach seemed available.

With the advent of new and even more complex technologies such as those summarized under the heading of “nanotechnologies” new processes were developed to address the broad implications such technologies might have on to not only industry and economic stakeholders but society or nature as a whole. This process often referred to as Technology Assessment or TA (e.g. *Kaiser, 2010*), and represents the highest possible level of decision-making regarding new technologies and has also been referred to as “new form of democratic decision making even beyond state boundaries” (*Bijker, 2013*). While TEMONAS can certainly support some or even many of the processes involved in such a Technology Assessment, its original remit and specification was much less broad, thus the final tool experienced a “re-christening” to Technology Monitoring and Analysis System.

TEMONAS Core Design Concept

Given the requirements of the call and the necessarily broader appeal for a more general tool, the consortium decided to design a tool that offers based on an object oriented database

- Multi-dimensional and multi-domain performance data analysis
- A novel embedded expert judgment mapping to determine "proximity-to-commercialization"

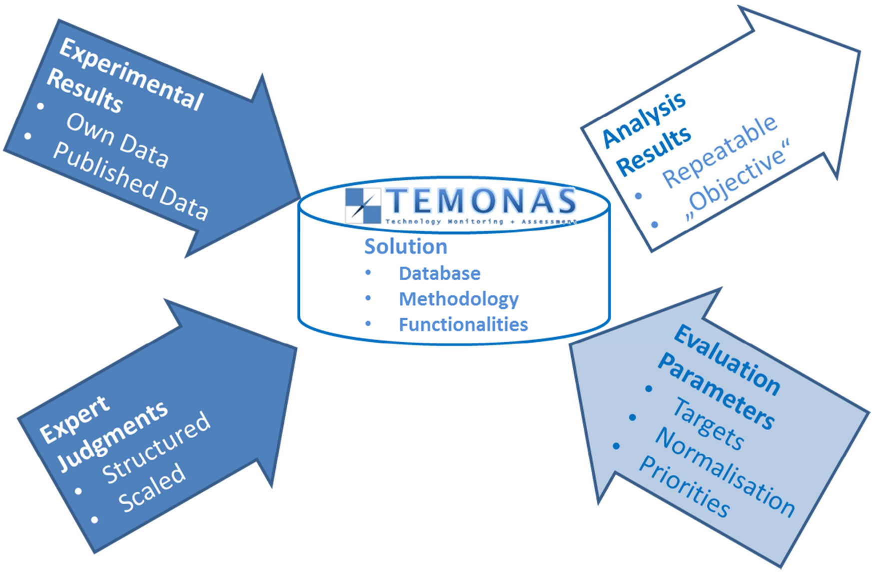


Fig. 7: Core Design of the TEMONAS Solution

The multi-dimensional approach enables the user to define groups of metrics according to evaluation dimensions seen as similar. In the version for the FCH-JU five such dimensions were implemented.

Fig. 8: The multi-metric, multi-domain approach to analysis in TEMONAS

This enables both a holistic assessment using advanced evaluation methods such as multi-criteria analysis but also in-depth investigations of individual performance metrics. Multi-domain refers to the fact that from a tool point-of-view the type of object that is described by its attributes can be anything that the user wants to document and analyze, as long as it can be differentiated from other objects. In the case of the FCH-JU the main objects will, of course, be hydrogen and fuel cell related technologies, but in a broader context, the FCH-JU may in the future be required to run benchmarking evaluations against a broad array of competing energy technologies, from Sterling engines to micro-turbines. While proper definition of technical performance parameters will be necessary, such comparisons will be easily facilitated.

As has been mentioned in the chapter before the need to analyze early stage technologies and be able to ascribe a proximity to commercialization was not only a critical request of the FCH-JU, but was seen as an important issue for strategic technology management. Being able to use external experts seemed logical also given the typical procedures used by both funding agencies and industry, however, their respective input needed to be "datafied" and structured. Thus the TEMONAS tool includes a module enabling the analyst to run an expert computer-aided expert judgment process, in which one or more experts give their opinion on critical dimensions regarding parameters that are according to innovation economics critical for success. The tool then supports an expert consensus process analog to a Delphi method.

Other important features of the tool are derived from the need for data quality management including data validation/authorization procedures and the knowledge of the consortium regarding the differentiated way performance data are typically reported and capabilities to deal with imprecise data. Data selection can be either be done using a graphically supported SQL query or pre-defined in the application tailoring process, the same holds true for data output which can either use the powerful graphic engine embedded in TEMONAS or be exported in widely accepted datafile formats for processing with other software packages.

V. The TEMONAS Project

Core Facts

The TEMONAS Project was coordinated by CLIMT – Claassen Industrie Management Trading GmbH from Graz, Austria.

The additional partners were

- PLANET Planungsgruppe Energie & Technik GbR, Oldenburg, Germany
- European Fuel Cell Forum AG, LUZERN-Adligenswil, Switzerland
- CEA-LITEN, Grenoble, France
- CSMS Janina Święch-Skiba, Pszczyna, Poland
- Bana Consulting Ltda, Lisbon, Portugal
- synergesis consult.ing Herbert Wancura, Graz, Austria

Budgeted Project Total Costs: € 1,800,602.00
Maximum FCH-JU Funding: € 1,132.046.00

The duration of the Project was extended by 3 months primarily to implement some additional requirements by the FCH-JU program office, such as secure data entry by external parties via a web-browser interface and thus ran from Sept.1, 2011 until May 31, 2013.

Project Structure

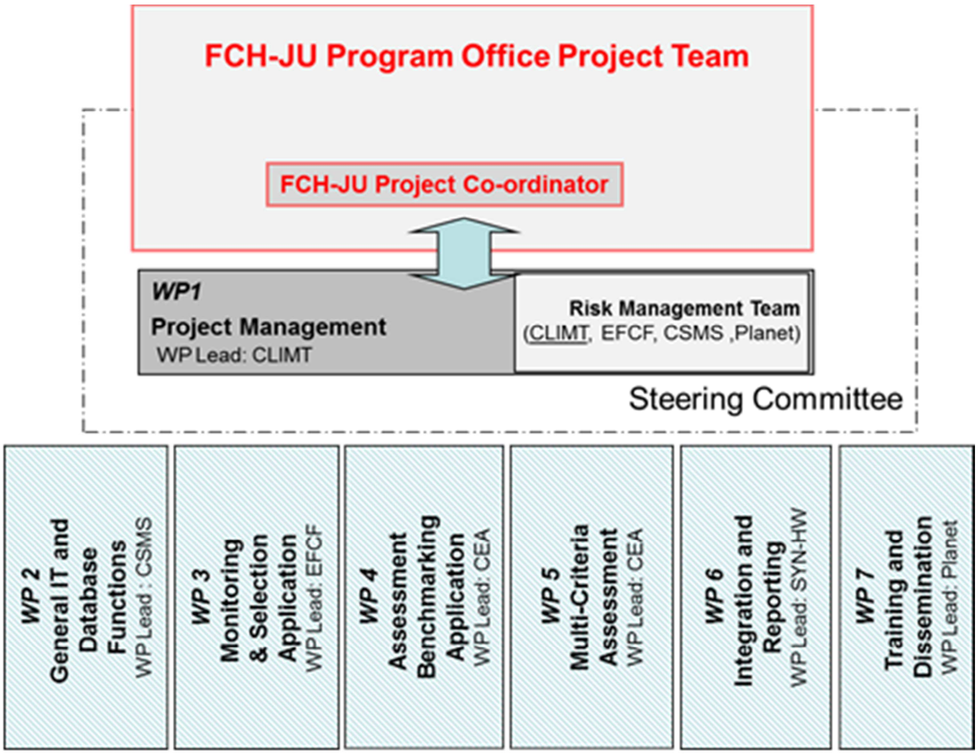


Fig. 9: TEMONAS Project Structure

The planned project structure, which is shown as an overview in Figure followed the modular structure (see Fig. 9) of the TEMONAS tool proposed in line with the requirements of the call. In total the project structure foresaw 6 Work packages + WP 1.

- WP1 Project Management
- WP2 General IT and Database Functions (In-/output, Workflow +Validation routines, Documentation and Handbook)
- WP3 Development of Monitoring / Selection Application
- WP4 Development Selection of Assessment/Benchmarking Application
- WP5 Multi-Criteria Assessment (non-linear evaluation)
- WP6 Integration and Reporting
- WP7 Training and Dissemination

The development plan was based on a number of assumptions among which was the ability to further develop the specifications in a close coupled process with the lead client FCH-JU. Thus, the workplan also foresaw an Inception Report (D1.1) in which the joint understanding of the actual specifications was to be detailed as a result of individual workshops to be held for each major function and application area. This specification and some variations were planned to be implemented in a process shown in Fig.10.

TEMONAS Development Process

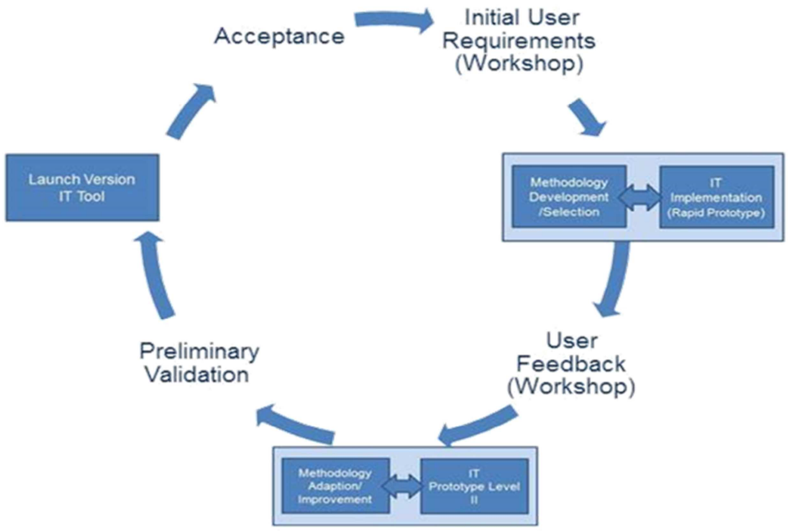


Fig. 10: Proposed Development Process for the TEMONAS Project

However, capacity constraints on the side of the FCH-JU programme office required a different process, which necessitated for the project consortium to work more independently receiving a first input in an early meeting (November 24, 2011) and then presenting intermediate levels of achievement at 3 meetings and via the deliverables (mainly D1.1, D3.6, D4.9, 5.12).

As the system development was based on an already existing “application builder”, which is a software that had been an important background know-how of the software development builder CSMS, and such an approach had better chances of being successful in a project environment where the client had not yet had the time/resources to develop a detailed understanding of its concept of a final or precise specification, it was decided to use and agile software development process applying some principles of extreme programming (*Ambler 2002; Wolf, 2005*). However, these methods require a very close link between user and programmer, something that would also not be possible for the FCH-JU programme office staff. Thus, a group of people within the consortium (mostly CEA, EFCF and PLANET) acted as “internal lead user” with CLIMT acting as application quality manager.

Another important difference between the original workplan and the implementation concerned WP3 “Technology Monitoring”. Two major changes occurred:

1. Monitoring was defined as time based evaluation of the development of performance data and thus, in principle used the same data as the assessment and benchmarking evaluations dealt with in WP4 “Technology Assessment (Benchmarking)”. This was solved by close cooperation between WP 3 and 4, in particular CEA and EFCF, but reporting the respective aspects in the originally foreseen deliverable structure.
2. The definition of a complex compounded index called Commercial Readiness Level (CRL), while in line with the evolution of use of such indexes e.g. by NASA or the US

DoD and other researchers (*Dent, 2011; Paun, 2011; Ratchev 2011*) , was found to have a number of methodical weaknesses. In addition, the broad range of query possibilities offered by the standard tools made the original concept of using it as a screening tool to limit performance data acquisition effort unnecessary. However, as has been argued in the earlier chapter, a tool for incorporating expert input in a structured format in order to be able to look at emerging technologies with limited published performance data and to be able to reach conclusions on proximity-to-commercialization in a consistent context, some of the original features of the CRL did make still make sense and thus were developed in a separate functional module called expert judgment mapping.

Other than those, the following additional issues came up and had to be dealt with:

1. As opposed to the DoW, where a purely Windows based and local input of data was foreseen based of issues of IT-security raised by the FCH-JU programme office during the negotiation process, later work on the case studies showed that "unearthing" performance data, agreeing on metrics and parameters, etc. could create a manpower requirement beyond the capacity of the FCH-JU programme office. In addition, the European Commission is planning to introduce performance data reporting in the Horizon 2020 research programme. It was therefore requested to develop a secure web browser interface for data input being the main reason for a project extension of 3 months.
2. Already from the beginning of the project cooperation with the US National Renewable Energy Lab (NREL) was sought, as the NREL has a broad database on performance data of their demonstration projects, which is in part made public via so-called Composite Data Products (*NREL 2006-2012*). However, due to various constraints on both sides such cooperation could not be established inside the project framework.
3. The form of integration of the multi-criteria analysis method MACBETH had not been defined in the DoW. One option was to run the two packages separately and off-line, i.e. data and evaluation parameters would be via a remote link on the M-MACBETH server of Bana, but this version did not look attractive as it would have eliminated the seamless user experience intended for the TEMONAS tool and also faced issues of version management. Another option would have been a full reprogramming of the MACBETH method, which would have created both issues of resource constraints at the partner CSMS and copyright issues. Thus it was decided to implement a third path: After methodological definitions described in D5.12, Bana produced and provided the core methodology as a dll-file to CSMS including the necessary interface information, CSMS embedded the dll-file into TEMONAS including joint testing and a full GUI development for the MACBETH methodology as well as output production. The functionality described in the DoW was thus realized in a seamless solution.

Summarizing, while the project experienced a few changes and a minor extension, its core development packages successfully developed and delivered an integrated tool for Technology Monitoring and Analysis that meets the functionalities required by the call document.

The methodologies and functionalities are described in detail in the respective deliverables:

- Technology Monitoring Report (D3.6)
- Technology Assessment Methodology (D4.9)
- Multi-parameter Comparison / Assessment Methodology Report (D5.12)
- Integration/Reporting Routines Report (D6.15)

These deliverables have been published on the internet via the website www.temonas.eu. However, it is necessary to register before one can download the reports to enable tracing and follow-up as well as avoiding potential misuse.

In addition, the project team and the FCH-JU programme office put significant emphasis on dissemination, thus apart from the scheduled trainings also positioned under WP7, this work package saw a number of activities:

TEMONAS Website

The TEMONAS website, www.temonas.eu, was set up for online information on the project and tool. Efforts were made to increase the amount of tool related information on the website as the tool began to take shape, so as to arouse interest among the online visitors for the tool enough for them to decide whether they want the tool or not.

Dissemination material

Informative items were designed and prepared for awareness at public events including:

- Leaflets and Flyers,
- Posters and
- Memory sticks.

These have been submitted under deliverable D7.22 – Project CD.

Conferences

However, due to various constraints, including timing, unsuitable conference themes and presenter restrictions, the conference publicity activities for TEMONAS were according to the following table.

Table 1: Attended Conferences

2012	City	Dates	Format
2nd International Conference on Leadership, Technology & Innovation Management	Istanbul	October 11-13, 2012	Paper
Fuel Cell Seminar 2012 November 5-8, 2012, Connecticut USA	Connecticut	November 5-8, 2012	Presentation / booth
FCH JU Review Day, Brussels, 28-29 November 2012	Brussels	November 28-29, 2012	Presentation

2013			
TISS Conference 2013, Mumbai	Mumbai	Jan 22, 2013	Presentation
PACITA Conference, Prague	Prague	March 15-16, 2013	Poster
Fuel Cell and Hydrogen Conference 2013, Birmingham	Birmingham	March 21, 2013	Presentation
Hypothesis conference, Edinburgh	Edinburgh	June 11-12, 2013	Presentation
Final Workshop	Brussels	May 22, 2013	Presentation

One or two partners were able to represent the consortium at each of the conferences, making oral presentations at most of the conferences, and a poster presentation at PACITA in Prague. We were also able to have a booth at the Fuel Cell Seminar in Connecticut. A report with details on the conferences has been submitted as deliverable D7.21.

Final Project workshop

On the 22nd of May 2013, the final project workshop took place at the FCH-JU offices in Brussels. This was to mark the end of the project; it was an opportunity for the final user training and hand over of the tool to the main client, the FCH JU. The final workshop also served as an opportunity to inform the other organizations in attendance about the TEMONAS tool.

VI. TEMONAS Functionality - Overview

Data Entry

Data entry generally is done using a variety of lists and libraries. These contain recurring basic definitions such as the parameter name, the SI unit, conversion factors, etc. data entry may be simplified by grouping input parameters to parameter masks or using special input wizard. Data fields may also contain formula.

Data quality assurance

In order to assure that only data of proper quality can be used for evaluation the system comprises a set of routines. Generally all data entered is assigned reliability level. This reliability level is typically assigned to the source of data. The logic behind this relation is that date the reported in renown peer reviewed journal has a different quality level than data in a general use paper. Once data is entered from the source all data has the same source related reliability level.

All data entered into TEMONAS is assigned a ”responsible analyst” and must pass through a validation/authorization process in which all newly entered data is placed under a condition of “in data entry” Once the data entry process is completed the data is placed at the disposal of the responsible analyst for authorization and the status is changed to “pending authorization”. Once the authorization has been made the data is “authorized”. As part of this authorization procedure the reliability of the data can be changed individually for each performance data point. However, doing so requires a comment by the responsible analyst justifying the change. Only authorized data can be used for further analysis or evaluation. An authorization can also be revoked whereupon the procedure starts at the point of “in data entry”. Proper workflow management routines, such as e-mail notification, support the handling of the authorization.

Data confidentiality

Also source dependent the performance data is tagged with a confidentiality flag. There are three confidentiality levels public restricted and confidential. Confidential data may only be handled by users having the corresponding user privileges and remain invisible to others.

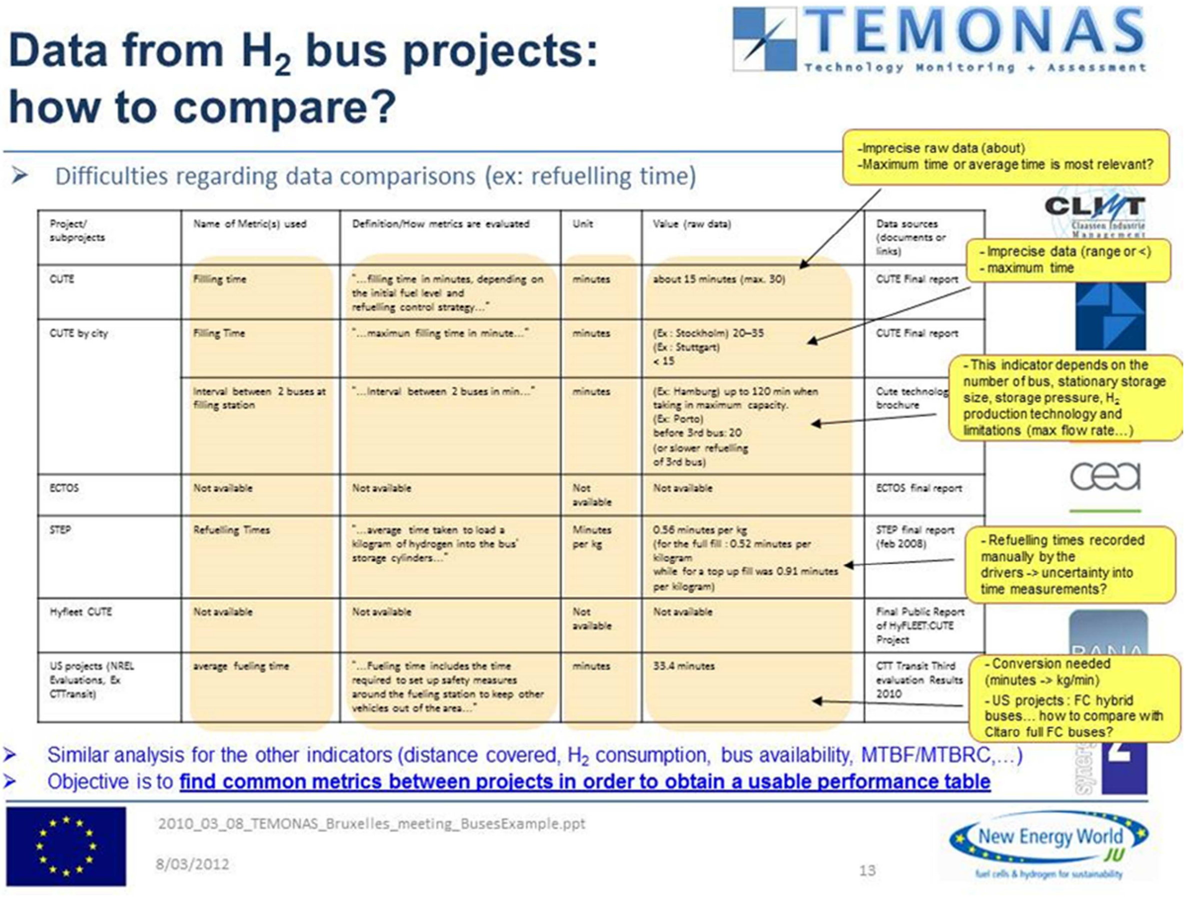
Special processes regarding data entry

Imprecise data

Data is sometimes reported in imprecise values for example of press release or project report stating that is specific technology had achieved a lifetime larger than 10,000 hours. The correct mathematically input is thus >10.000 hr. However, such an input creates problems for queries as asking for any number larger than 10,000 will be returned as “true”, and thus the object with a performance value >10.000 will be returned as part of the query. In reality it is likely that the actual performance value was just slightly over 10,000 else the report would have stated higher arithmetic number. In such a case the program will open a window requiring the person entering the data to define a range or deviation tolerance with respect to the data entered. This enables now clear logic boundaries for inclusion in queries. For example, if the request is for CHP- efficiency of 76%, and object with efficiency data of >74% and a range given at +6% deviation (i.e. maximum 80%) will be returned as part of the query result.

Inconsistent data reporting

A major issue is that different projects or projects run by different parties, funding agencies, etc. do use different "yardsticks" to measure and, more importantly, report similar types of performance. The following example shall exemplify the issue. When analyzing Busses in public transport applications regarding lifetime of the systems we find different metrics, such as "miles between unexpected road stops in [mi], MTBF (Mean Time Between Failure) in [hr], Availability [%], or with respect to refueling time the following situation:



Project/ subprojects	Name of Metric(s) used	Definition/How metrics are evaluated	Unit	Value (raw data)	Data sources (documents or links)
CUTE	Filling time	"…filling time in minutes, depending on the initial fuel level and refuelling control strategy…"	minutes	about 15 minutes (max. 30)	CUTE Final report
CUTE by city	Filling Time	"…maximun filling time in minute…"	minutes	(Ex : Stockholm) 20–35 (Ex : Stuttgart) < 15	CUTE Final report
	Interval between 2 buses at filling station	"…Interval between 2 buses in min…"	minutes	(Ex: Hamburg) up to 120 min when taking in maximum capacity. (Ex: Porto) before 3rd bus: 20 (or slower refuelling of 3rd bus)	Cute technolog brochure
ECTOS	Not available	Not available	Not available	Not available	ECTOS final report
STEP	Refuelling Times	"…average time taken to load a kilogram of hydrogen into the bus' storage cylinders…"	Minutes per kg	0.56 minutes per kg (for the full fill : 0.52 minutes per kilogram while for a top up fill was 0.91 minutes per kilogram)	STEP final report (feb 2008)
Hyfleet CUTE	Not available	Not available	Not available	Not available	Final Public Report of HyFLEET:CUTE Project
US projects (NREL Evaluations, Ex CTTransit)	average fueling time	"…Fueling time includes the time required to set up safety measures around the fueling station to keep other vehicles out of the area…"	minutes	33.4 minutes	CTT Transit Third evaluation Results 2010

Fig.11 Example Bus Operating Data (from Presentation Montignac/Mazzucchi in Brussels, March 8, 2012)

In this case TEMONAS enables the forming of so-called Parameter groups, which all measure the same ontological attribute, e.g. reliability using different parameters, such as the ones given above. Search functions can then also address the broader group of parameters even though on an individual level the parameters may not be directly comparable or convertible as this would require information not available in the source, such as average speed of a bus for converting "miles between unexpected road-stops" into individual "Times

Between Failures" which could possibly be further processed into MTBF. In many cases this may not even be sensible only for very high level requirements, as the individual operational profiles may vary too much thus rendering comparisons meaningless. However, in most cases, data is reported as there are target values assigned to such parameters. This enables a simplified normalization as % of target thus making even such diverse performance parameters comparable. Furthermore, normalization could also follow the more complex procedure applied in the multi-criteria evaluation module.

Data Evaluation

The TEMONAS tool offers 5 main analytical functions:

- Assessment
- Benchmarking
- Monitoring
- Multi-criteria comparison
- Expert Judgment Mapping (TRL/xRL portfolios)

Definitions

Assessment
Assessment deals with the analysis with the actual performance of a single research object or project against target metrics.

Benchmarking
In Benchmarking various research objects or projects are compared to each other and may also be jointly compared to targets.

Monitoring
Time dependent analysis of assessments or benchmarks for one or more research objects

Multi-criteria comparison
A multi-parameter evaluation according to the MACBETH method involving computer-aided social processes for normalization and priorisation/weight determination leading to aggregate comparisons or steps thereto.

Expert judgment mapping
An interactive rating of a given technology or technology/application combination whereby experts rate a variety of metrics related to technology maturity and manufacturing readiness as well as non-technical barriers to innovation together with a qualitative market assessment. Analog to a Delphi process this rating may be repeated for expert consensus forming.

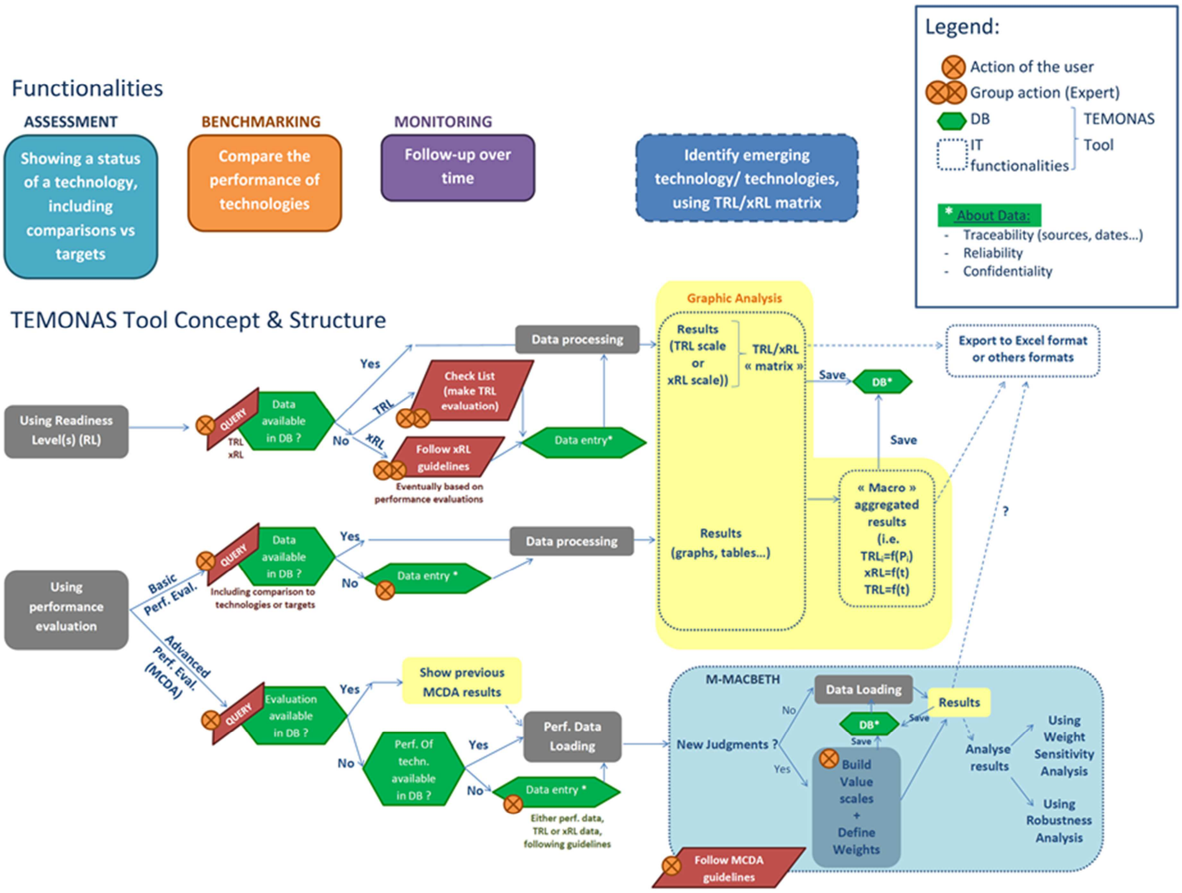


Fig. 12: Generalized Functionality Map of TEMONAS

The processes of evaluating data can thus take place at different levels:

(i) Standard evaluation (simple process)
(ii) Advanced evaluation (multiple step escalation towards MCDA)
(iii) Expert judgment (with or without data support from i, ii)

Standard evaluations

Two examples of a standard evaluation are given in the graphs below. The first one would be the monitoring of a cell performance over a three year period with the corresponding targets. The second graph would be used to illustrate a more general development in a sector, in this case Hydrogen Rail technology by showing the power of the traction units evolving over time.

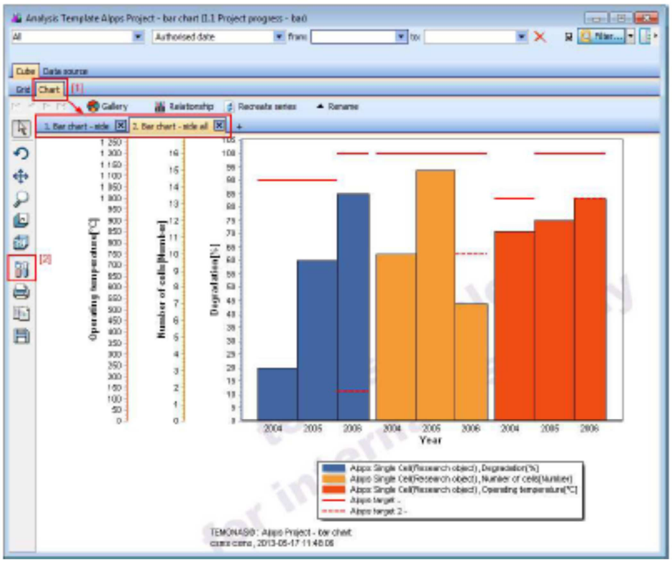


Fig. 13: Simple monitoring of assessments regarding the performance of a cell in TEMONAS

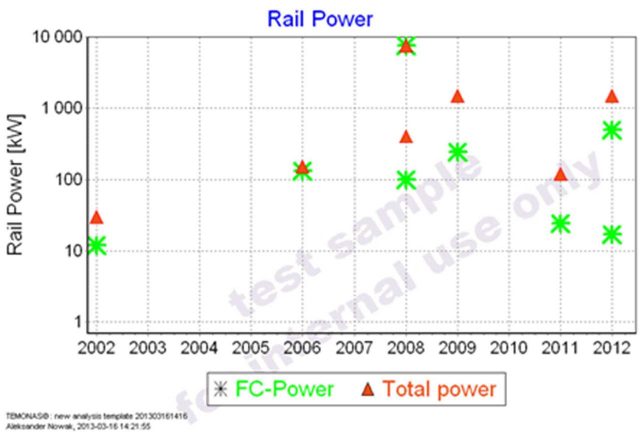


Fig. 14: Plotting the development of power ratings of an hydrogen application over time

Particular emphasis was placed on being able to compare a large number of parameters via the radar/spider graph. A TEMONAS Specialty is that each axis on such a spider graph may have its individual scale thereby avoiding the typical problems of readability. Another important format is to express those in line with the gap/proximity-to-target concept detailed earlier.

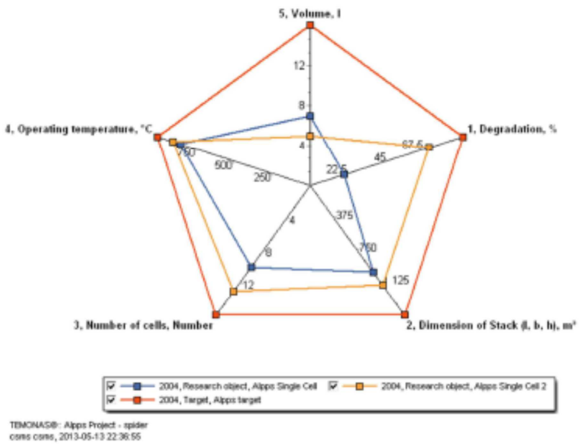


Fig. 15: Multi-dimensional radar/spider plot of an example of an RTD performance

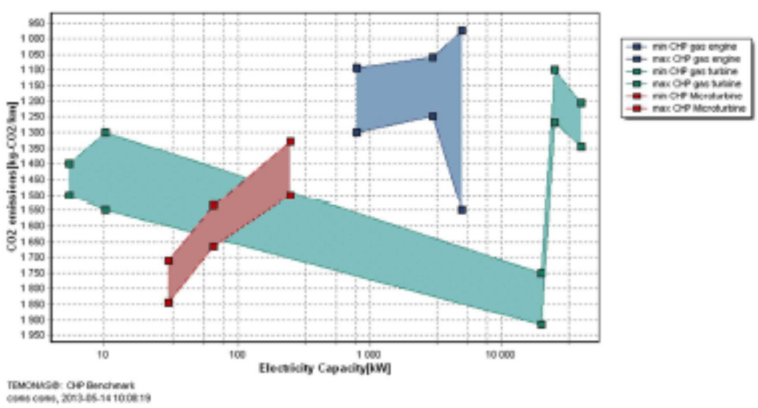


Fig. 16: Graph comparing a single performance parameter of different technology options with min/max range of performance

Advanced evaluations

Advanced evaluations are those that can be applied for multi parameter or multi criteria evaluation or if they are necessary to compare performance of different versions of a technology that is reported in either vastly different scales or using different parameters which however belong to the same ontological attribute.

“Simple” Normalized Data

In this particular case actual performance data is converted to normalized data via simple normalization function, i.e. 0-100% of target. This helps in keeping complex graphs readable but is also sensible if one sees the primary ambition of a technology program to reduce the gaps between target values and actual performances and thus may be useful also when comparing program performance on an international level.

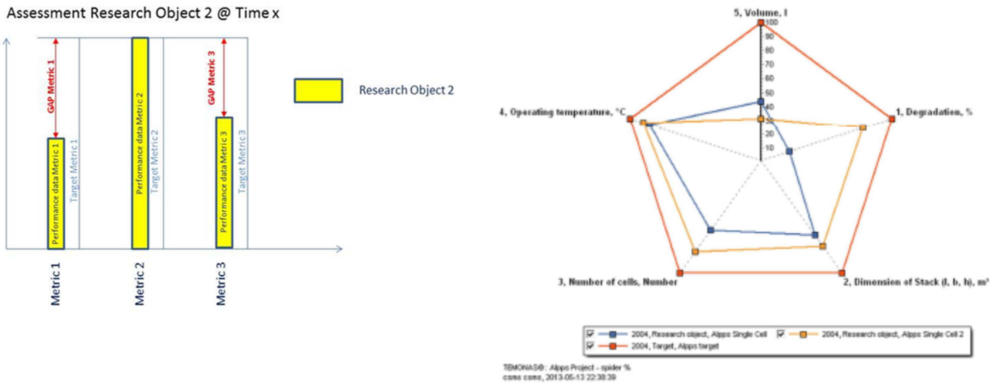


Fig. 17: Simple normalized data for gap analysis also in a target based radar/spider plot

Multi-criteria comparison using MACBETH

TEMONAS contains an integrated variant of M-MACBETH as applicable to the type of multi-criteria evaluations typically necessary in a technology evaluation framework. In this function the objective of multi-criteria comparison is achieved via a two-step process:

- Normalization
- Generating a weighed/aggregated result

Fig. 18: Normalization using the MACBETH Method embedded in TEMONAS

The normalization in this case is built using a social process whereby the users define the normalization functions via selecting acceptable and satisfactory levels and forming a qualitative rating matrix between those thresholds based on a seven step scale ranging from “no difference” to “extreme difference”. It follows from this that this evaluation process needs a very clear reference to boundary conditions, e.g. compact car and should preferably have quantitative targets (see Fig. 18 above)

In a second step this evaluation result of a normalization may then be used to also determine weights or priorities to parameters which can then either be looked at individually or based on their weights the aggregated into single scales of attractivity. This process enables aggregation of multiple parameters into a single consistent level of attractiveness which may be used as an input to the decision making process.

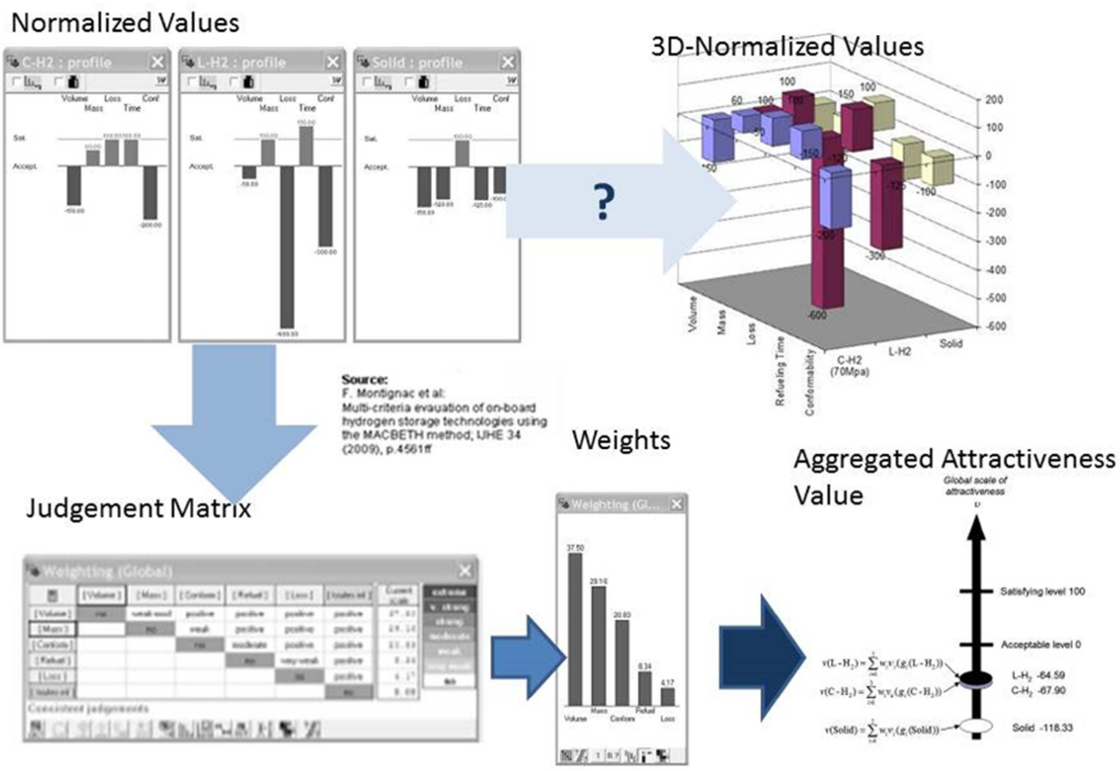


Fig. 19: Defining weights and aggregating attractiveness in the MACBETH Method embedded in TEMONAS

Expert Judgment Mapping

This is a separate module in TEMONAS. As has been mentioned it serves for structuring expert input regarding technology evaluations thereby "datafying" the expert input. It may be used to both judge the potential of new technologies as they are appearing on a "radar" of a more permanent observatory function and as an instrument to analyze the "proximity-to-commercialization" or commercialization readiness (e.g. *Aasrud, 2010*). In principle, the process is based on analyzing each technology with respect to the following groups of metrics:

- Technology maturity (Technology Readiness Level, TRL)
- Industry Supply Readiness (Manufacturing Readiness Level, MRL_{new})
- Non-Technical Barriers to Innovation (Framework Readiness Level, FRL)
- Policy Congruence Level (PCL)

As well as three market status descriptive metrics:

- Demand Development Status (DDS)
- Market Attractivity (MA)
- Relative Competitive Advantage (RCA)

Whereas TRL is identical with the NASA TRL scale and the MRL_{new} follows the NASA /DoD variant (*DRC*) closely -it reduces the early stages to one and adds a production level typical for mass markets; FRL and PCL are new and qualitative constructs that are compounded qualitative scales each.

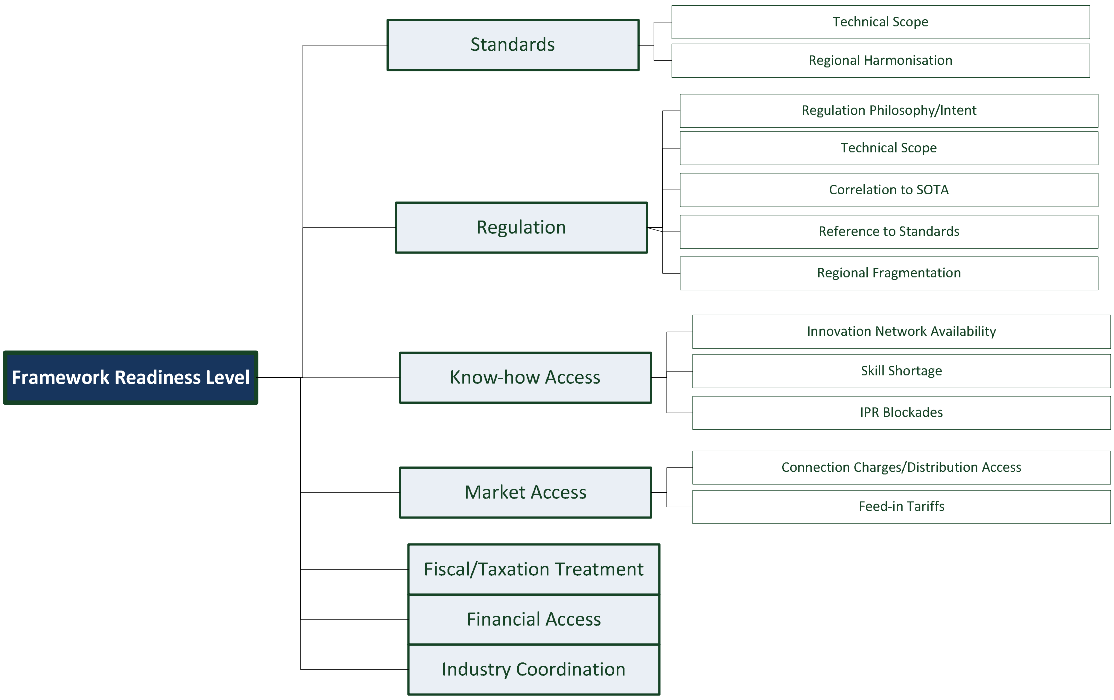


Fig. 20: The construction of the Framework Readiness Level FRL in the TEMONAS System measuring the Non-Technical Barriers

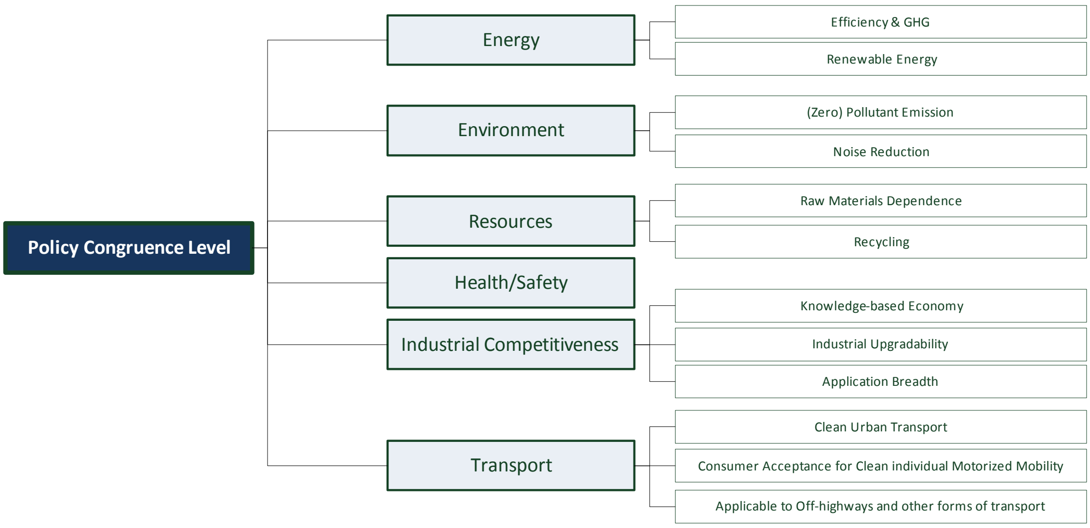


Fig. 21: The construction of the Policy Congruence Level PCL in the TEMONAS System

The market status description starts with the Demand Development Status, which is a ranking scale attempting to use the product life cycle model (Rogers 1995), but with an expansion in the early market phase.

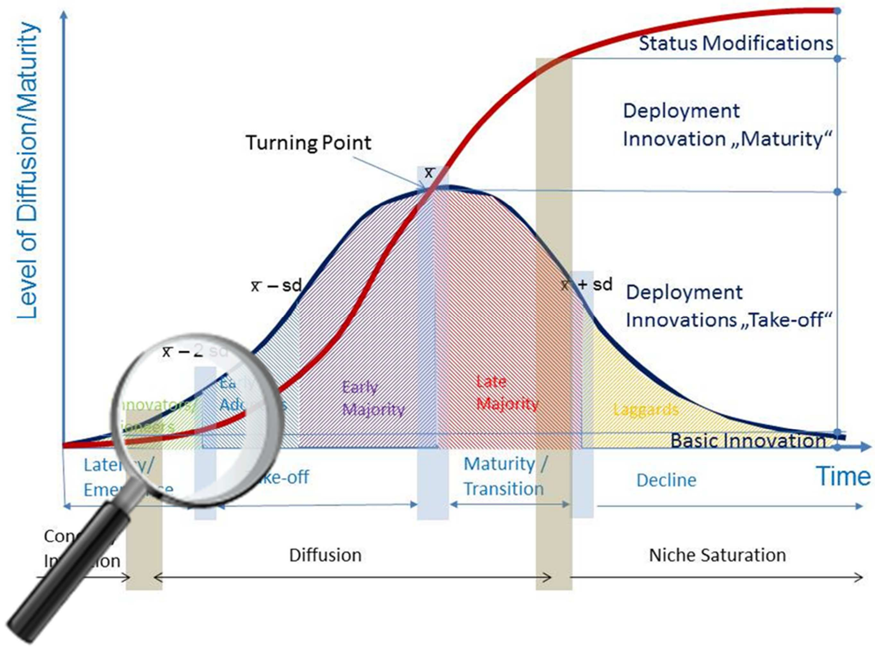


Fig. 22: The Product Life Cycle and the focus of the Demand Development Status DDS parameter included in the TEMONAS EJM-Module

The actual ranking scale has been defined as listed below.

Table 2: Demand Development Status Ranking Scale

DDS	Synoptic Description	Detailed Description
1	First User exposure	Proof of concept tests with enduser presence. Product is still operated by developer. Typically one or two pioneering suppliers
2	Enduser Demonstration Start	First Endusers are ready to use the system in a controlled project environment. Operators are by the enduser, close manufacturer assistance, no charge for product, but enduser at least partially taking risk for operating expenses. Similar to Alpha Testing . Still a very small number of suppliers . No real market, as there are no sales, but a Virtual Herfindahl-Hirschmann Index (HHI)would be betwenn 1..0,5
3	Increased Demonstration activity	Multiple demonstration projects also increasing in scale, including repeat structures and 2nd/3rd generaytion of product/system, similar to Beta testing. As the technology creates more visibility the number of suppliers is slowly rising, but still a virtual market only. Virtual HHI 0,8..0,35
4	First purchases in Strategic Niches	Purchases take place in a typically still strongly subsidy dependent form. Operators asssume full ownership for the first time. Purchases are still small compared to the typical incumbent technology lot size. Beginning of a real market development . Real HHI 0,8 ..0,35
5	Multiple Strategic Niches are buying regularly	Technology finds ist first few niches which broaden ist exposure and enable new learning and more rapid product improvement as well as tailoring of scope. First step at market diffentiation become visible. Industry starts to really organize itself and works coordinated to demonstrate its advantages also asking for support. HHI around 0,4 ..0,25
6	Growth in a regulated environment	Authorities accept the benefits of the new technology/product/system and are willing to grant a regulated market, e.g. via subsidies for investment, feed-in tarriffs, etc. Often accompanied by policy oriented targets. First supplier companies report growth and significant growth rates, attracting secondary financing from the market , in some regions even sucessful IPOs. Competition moves global. HHI below 0,25
7	Growth without regulative assistance	Regulated markets have helped build sufficient scale that economic sustainability is achieved without regulative assistance. Growth comes both from organic broadening of enduser appeal and base, but first consolidation moves are occurring eliminating weaker players adding M&A growth elements. Market leaders are profitable and attractive investments, thus full engagement of financial markets where available. Full global competition. HHI between 0,2 and 0,1
8	Saturation/Maturity	Market growth has dissapeared, even segment optimisation and further internationalisation generate no or only very moderate growth. Profitability declines and a number of players are looking for exit strategies, offerning significant consolidation potential. Cost leadership strategies dominate with very sophisticated value chain management. Bundling occurs regularly where legally possible. HHI may increase again subject to intervention by anti-trust authorities.
9	Decline	Market shows only decling volumes, the majority of players exit the market, profitability is the exception and only found in niches. HHI may yet increase but due to the declining relevance may not provoke anti-trust action.

The market status information is completed by two more qualitative compounded indexes:

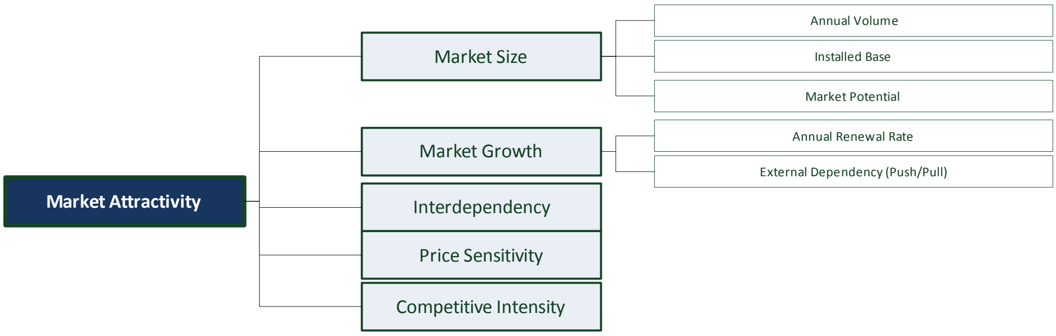


Fig.23: The construction of the Market Attractivity Index (MA) in the TEMONAS System

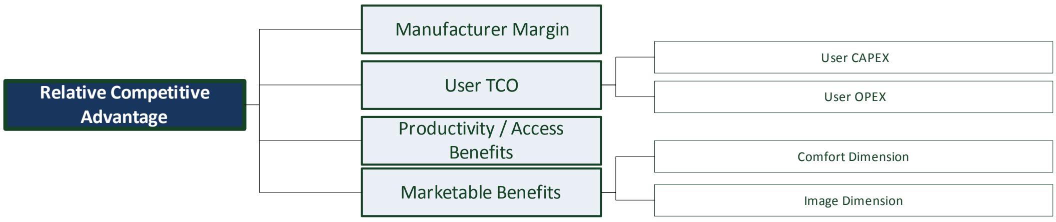


Fig.23: The construction of the Relative Competitive Advantage Index (RCA) in the TEMONAS System

The process of entering data is supported by a simple graphically supported input system as shown below:

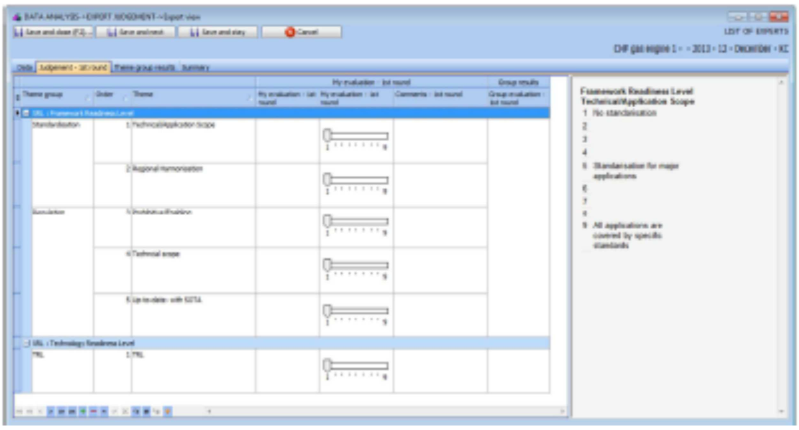


Fig. 24: Screenshot of the TEMONAS EJM Module for entering expert judgments in the 1st round

And may be repeated showing the range of ratings of all experts participating in the evaluation.

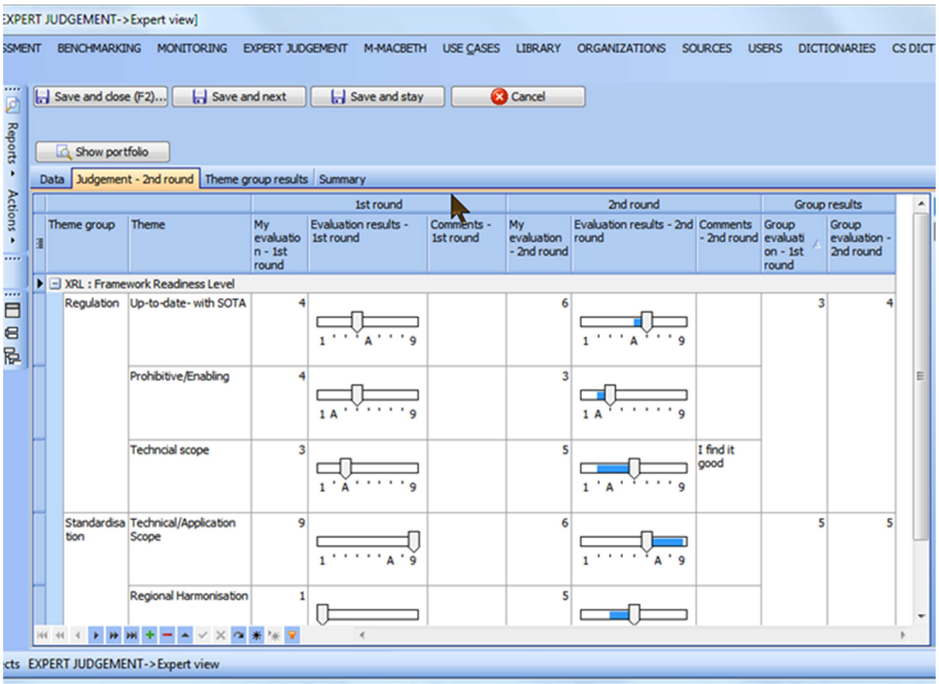


Fig. 25: Second round of an EJM rating entry in TEMONAS including the range of judgments given in the first round

Thereby a Delphi type process of expert consensus forming is achieved. It is important that if an expert wants to select a value at or beyond the range of judgments of all other experts she/he is requested to file a comment as such outliers in an environment of high uncertainty will be highly informative (*Saffo, 2007*).

A typical output would then take a portfolio type graph where the values can be placed on a matrix of EJM xRLs.

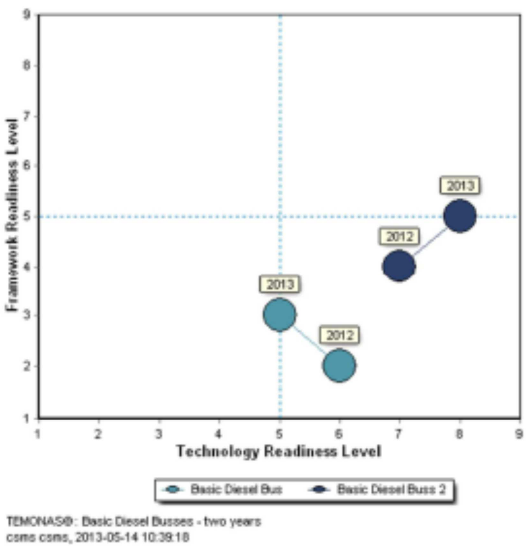


Fig. 26: Example of a plot depicting the development of EJM ratings over time in TEMONAS

By analyzing the temporal development of the EJMs different parameters vs. it is not only possible to draw conclusions on “proximity-to-commercialization” and/or emerging new technologies but also develop an understanding of key variables influencing that position, e.g. when a technology achieves positive results in most of the maps but “is held back” in the experts opinion by an unfavorable regulatory environment which then may actually represent an actionable item to address if in the remit of the agency performing the analysis.

VII. TEMONAS Structural Elements

General Architecture

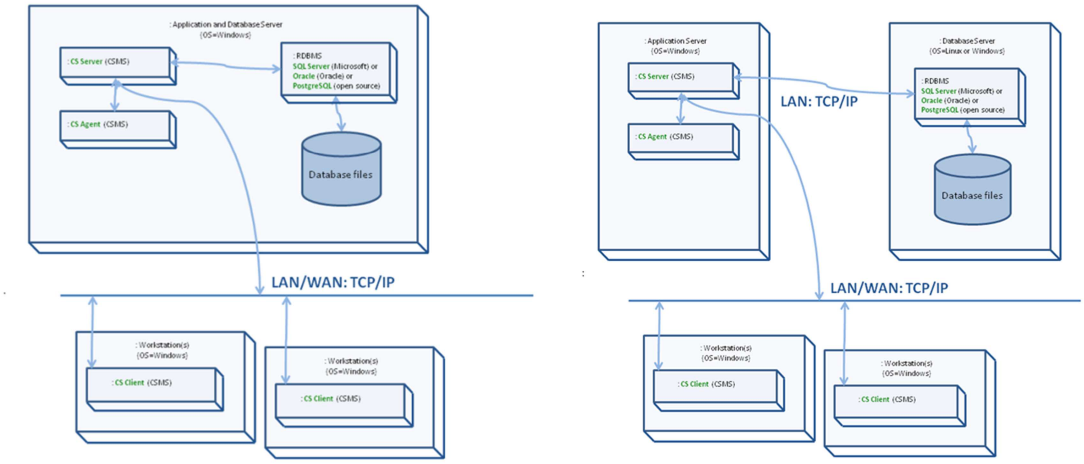


Fig. 27a/b : TEMONAS (CS-System) in common machine architecture (a, left) or distributed machine architecture (b, right)

TEMONAS is based on CS System. CS may base upon any of the three most popular RDMS systems: PostgreSQL, Oracle or Microsoft SQL Server. However, some solutions specific for TEMONAS foreground may be depending on the type of the database. For most CS applications, taking into account good performance and easy administration, the SQL Server is the optimal solution. Considering all circumstances and conditions at FCH-JU resulted in selecting PostgreSQL with the EnterpriseDB extension. The CS-System is a high performant secure multi-user database application in a three-tier system consisting of:

- Relational database management system
- CS Server
- CS Client

The CS System is a basically an interpreter creating the respective user interfaces based on the configuration stored in the RDB. This includes:

- Definitions of the object oriented database structure
- Privileges for users and user groups
- Definitions of user screens
- Data filters
- Reports and outputs
- Special functions (interpreted code e.g. the dll file delivered by Bana Consulting representing M-MACBETH)

The CS system may either run on a common machine with the RDBMS (preferred solution) or may actually be run on two different machines, but then a gigabit LAN Connection between the two systems is required (see Fig….above). The server machine may also be virtualized e.g. using *VM Ware* or *XEN hypervisors*. The performance of such a virtualized server must be equal to the specified minimum performance of a common server. Detailed hardware and Software specifications were issued to the FCH-JU Programme office and suitable hardware has been provided.

Objects

The TEMONAS tool foresees the following objects:

- Research program
- Call /Topic / Project
- Target
- Source
- Research object / Aggregated (Meta) Research object
- RTD organization
- Standard/ operating conditions
- Parameter values
- Query
- Query result

An overview of these objects is given in the (simplified) graph below:

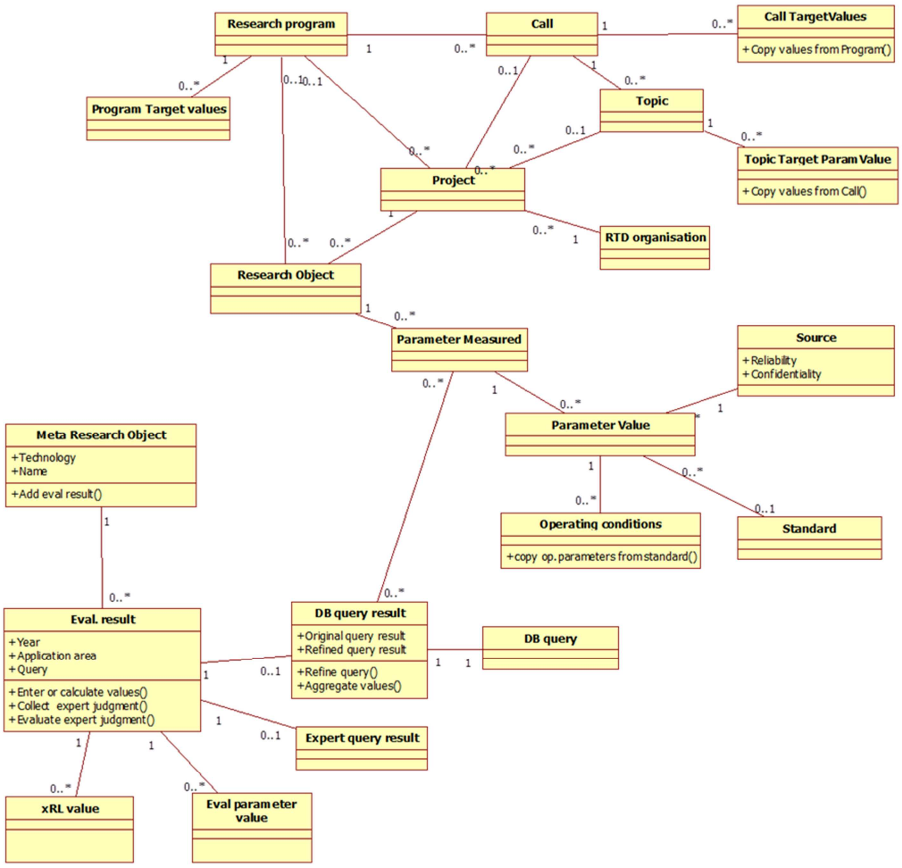


Fig. 28: Simplified graph of objects in TEMONAS

Research Object

The core element of the TEMONAS system is the Research Object (RO).

Fig. 29: Research Object Definition

The research object is the smallest reported unit for which discrete information can be documented. It may be at different aggregation levels from material to full vehicle or power plant and a project object has to have at least one research object attached to it. Again, for the research object the project targets and the topic targets are relevant for comparison. Performance data can be entered in all five dimensions and be used to compare the research object against targets and other research objects of similar characteristics.

Target Objects

Target objects are the formulation of quantitative or qualitative targets inherent to every level of project management from program level to individual research object if so discernible. They serve as yardstick for the assessment of each respective object progress but also can be optimized by themselves in being benchmarked as part of a call or topic development process.

Operating Conditions/ Standards Object

It is well documented that the performance of technical objects depends on the operating conditions. Thus it is important that actual performance data is qualified by the operating conditions as part of the evaluation boundaries. In an ideal case, all performance data is reported according to (international) standards which, however, is unlikely in nascent industries where standards are only slowly emerging. If existing, standards objects shall be used and their use be enforced by the analyst. The hydrogen and fuel cell world still is in its infancy there, so there are currently very few universally applied test standards. However, increasing standards maturity would indicate that this will change in the future.

Aggregated Research Object (Meta Research Object)

The aggregated research object formerly in some documents referred to as meta research object serves as a yardstick on high aggregation level to assess the relative position in the competing market landscape. Such an object for example would be an urban bus with a transport capacity of up to 80 people, or a forklift in the two-ton lifting class, or an urban 2-seat motorcycle with less than 250 kg, or a car in the C/D-segment. Such classifications allow a direct comparison on a high level with other either incumbent or competing system configurations. Performance data of these product/product group objects are derived as statistical averages of research objects falling under this category or may be entered directly if there are only sources containing already aggregated information on a group of specific research objects e.g. all hydrogen busses of a project operating in a city or all cars using Generation 1 FC powertrains in a demonstration program.

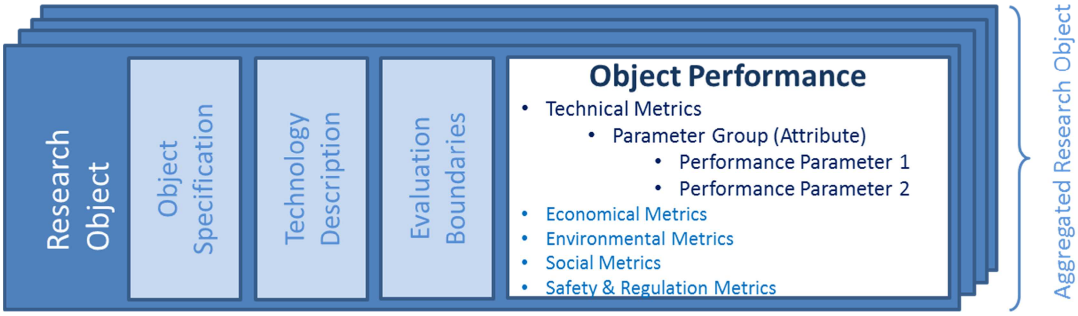


Fig. 30: Definition of the Aggregated Research Object in TEMONAS

Source Object

The source object is the source of any information entered into the data base. This may be anything from a verbal personal communication to scientifically reviewed publications and confidential project deliverables. The source defines among others the confidentiality level of the data, the quality and reliability of the data derived from it as well as unless given otherwise the time axes as to which the data is classified.
If such publication relates to a project the source and the project need to be linked. In case the lead author is not yet defined as an object as RTD-performer such an RTD organization or performer object has to be defined.
As stated earlier in the document from a number of perspectives it would be advantageous to directly store the source with the data and the TEMONAS system is designed to do that. To use a most obvious example, is a much simplified process during data authorization/validation: An entered performance value may look obscure to the responsible analyst and may require examination if it is a result of a data entry (a.k.a “typo”) type mistake or if the source has been quoted correctly. If in such a case the owner is forced to organize the source again according to some literature identification data, the risk that such verification process will be abandoned is increased. However, the TEMONAS consortium acknowledges the issues that might exist with respect to copyright restrictions. In principle, a number of measures to ensure compliance with the copyright may be implemented in the TEMONAS solution ranging from typical warning dialogs to opening restrictions etc.

Other objects

Program/Call/Topic/Project Objects

Program objects describe the highest level of integration of efforts. They are mainly characterized by high level targets such as budget, number of vehicles to be demonstrated and sometimes highly aggregated technical targets such as target cost or durability.
Examples of such programs are the MAIP of the FCH-JU, the US DoE hydrogen and fuel cell initiative, the SECA initiative, the Palm power initiative, the national program of Germany

NIP/NOW, etc. Each program object typically consists of depended sub objects such as research programs for application areas which again is then having calls topics as well as projects and research objects related to these projects there. So their actual performance data is resulting as mathematical aggregation of lower level performance data entered.
In case research programs are structured as per application area the application area is similar to a program object but restricted to an application.
The call object describes a call for proposal and its respective meta objectives as a descendant of the program objective. Once again it may also have specifics with respect to application area.
The topic object is a descendant of the call object and serves primarily to define the corresponding technical targets which in many programs are defined in the individual call topics.
The project object is the lowest organizational level for the program management. A project is defined by a source, a corresponding research organization in the lead and a list of partners, project specific targets in addition to topic targets to which the project is answering. Such a project may have one or more discrete research objects that are all worked on and reports being developed.

RTD Organization/Performer Object

The RTD-performer is the actual organization or researcher doing the work with respect to the data being published. In principal it is inferred that the publishing authors or organizations are the actual RTD-performers in absence of other references. The main information or course is typically organizational such as address, department, contact information and responsible person if clear.
Research organizations can be used as classification and sort field, thus also enabling a cross program evaluation of the performance of research organizations with respect to typical progress achieved by them.

Data

TEMONAS uses and processes a broad variety of data. They can be classified in principle in:

- Performance data
- Descriptive data

Performance data

Performance data may both result from actual measurement or modeling effort and comprise any form of parameters such as technical or environmental performance largely reported in physical values, economic data like cost per unit or progression ratio, but may also be related to social metrics such as awareness or acceptance values.

Two specific additional performance data types exist:

- Dependent performance data, i.e. data calculated from primary performance values, e.g. power or area specific resistance of a cell calculated as a result of voltage and current data following a fixed formula or performance data generated as a result of a special process, e.g. either by calculating statistically the performance of an Aggregated Research Object (ARO) from the individual performances of all research objects fitting the definition of the ARO, or as a attractivity score based on the scenarios developed in the MCDA module using MACBETH procedures.
- Indirect/inferred performance data, these are data resulting from a separate judgment process and may also contain statistically processed individual values, in particular these are the values generated in the expert judgment mapping (EJM) module.

Descriptive data

In order to properly sort or classify the data for meaningful query results TEMONAS requires a significant number of descriptive data:

Descriptive data for the Research Object / Aggregated Research Object

An overview of the scope of descriptive data can be seen in the following Fig….. It follows the definition of the object, relates it to program, call, topic and project, defines the technology both in terms of type and aggregation level, allocates it to an application area if unambiguously possible, and sets the evaluation boundaries including operating/testing conditions.

Similar descriptive trees exist for the following objects

- Program/Call/Topic/Project
- Source
- Research Organization
- Target

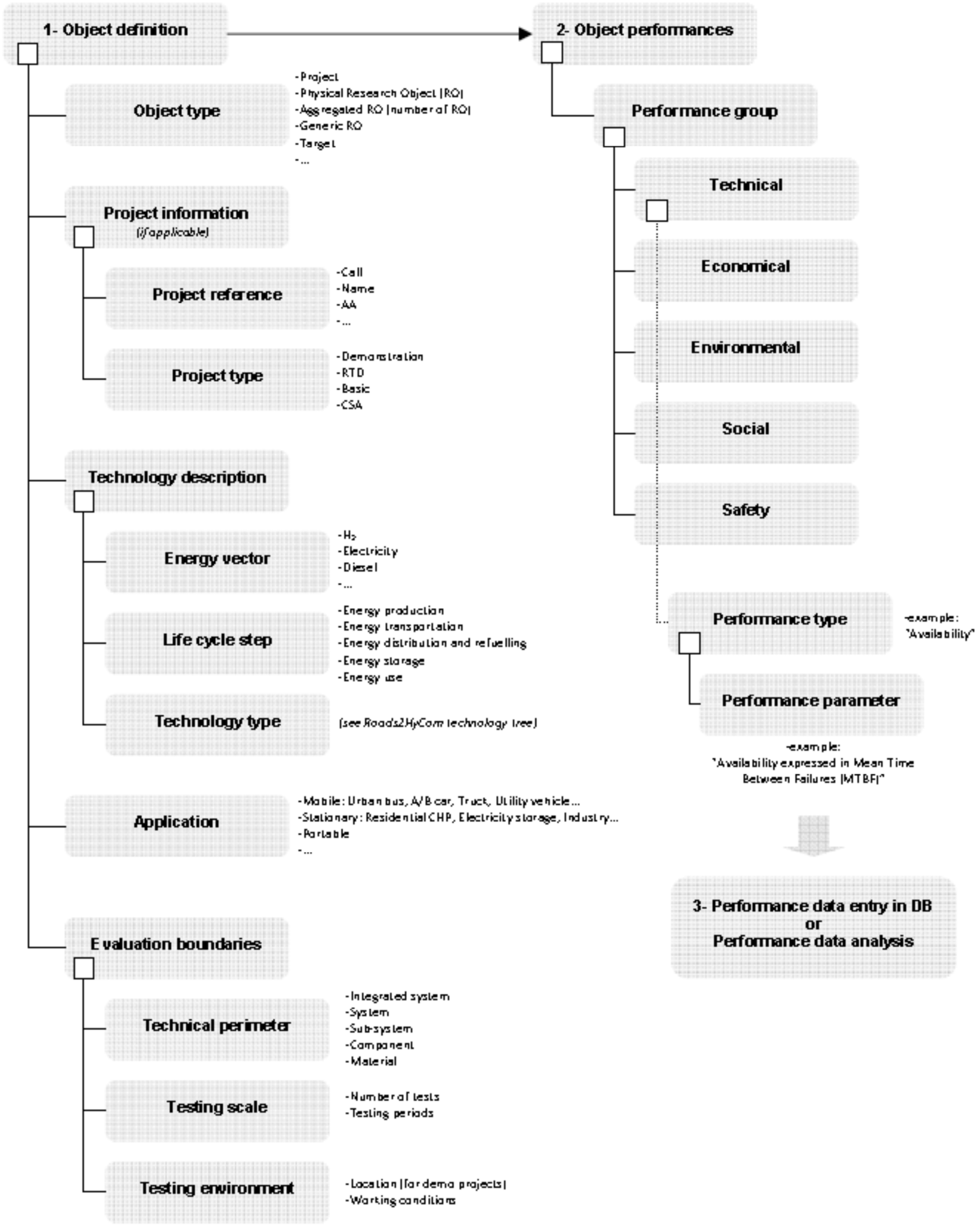


Fig. 31: Descriptive and performance data map for a research object in TEMONAS

This “overhead” may look excessive, but is seen as necessary to run all the evaluations the FCH-JU is foreseen to use. At the same time many of these data fields need to be inputted only once e.g. when a new project is being added. Filling in new performance data then is much simpler.

VIII. Summary and Conclusions

The TEMONAS Consortium realized the requested integrated Technology Monitoring and Assessment (TMA) solution within the budget and with only a minor delay which was largely due to implementing an additional functionality that was seen as necessary by the FCH-JU program office, namely the possibility for secure performance data entry directly by project managers which may be required as a result of future contract stipulations (*Baumgartner, 2013*). The tool was validated using case studies on a variety of Aggregated Research Objects from the different Application Areas using only published literature data as the access to deliverable and documents submitted to the EC or FCH-JU and containing critical information were rated confidential by the respective consortia and the TEMONAS consortium members thus had no access to these documents. Such information will have to be entered by the FCH-JU or another Commission service as was also already foreseen in the call.

The tool comprises a data input section including specific data quality management routines and libraries as well as sample parameter masks which can easily be adapted by the user. The data quality management is based on assigning each data a responsible analyst, source quality and a validation/authorization workflow which enables the responsible analyst to change the “quality tag” of individual data albeit with proper documentation only. Generally all changes to data and evaluation parameters or routines are logged together with the identity of the user performing the change thus ensuring high transparency. Outputs can be produced individually by each expert using both a graphically supported SQL-Query editor and a powerful graphic data presentation engine. The tool also contains pre-customized reports that have been defined together with the FCH-JU programme office to reduce analytical effort for those users who do not work with the system on a very regular basis.

In terms of analysis, TEMONAS supports technology assessment, benchmarking and monitoring in simple and advanced stages including a multi-criteria comparison based on the MCDA method MACBETH. The “radar” function” and the determination of “proximity-to-commercialization” are realized using a novel method where experts are asked to deliver judgments not only regarding the widely known and accepted Technology Readiness Level but expanding the concept and comprising further elements influencing innovation success according to pertinent research, such as Non-Technical Barriers, Policy Congruence while simultaneously also evaluating market parameters such as Demand Development Status, Market Attractivity and Relative Competitive Advantage.

The dissemination efforts have shown that this combination of features appears to be quite unique and attractive as it can either support in a very structured and transparent form stage-gate or gateway development philosophies embraced by many industries or deliver a sound decision support and documentation support tool for a wide variety of RTD financing organizations from public agencies to venture capital and private equity firms. Thus the TEMONAS Consortium will not only continue to support the lead user FCH-JU but has started active marketing efforts for broader exploitation.

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