This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 871106

Deliverable Number: D9.1	**Due date: October 2021**
Deliverable Title: Inventory of needs and potential **WP number:** WP9 **Leader Beneficiary:** CNRS **Deliverable type:** Report **Dissemination level:** Public	**Reporting period**: RP2 **Issue date**: June 2023 **Author**: Oliver Portugall **Reviewers**: ISABEL Coordination Board

ISABEL

Improving the sustainability of the European Magnetic Field Laboratory

D9.1

INVENTORY OF NEEDS AND POTENTIAL

REPORT

Start date of the project: 1st November 2020

Duration: 48 months

Project Coordinator: Geert Rikken – CNRS LNCMI (P1 - CNRS)

Contact: isabel@lncmi.cnrs.fr

Version	Modifications	Date	Authors
1.0	First draft	09.05.2023	Oliver Portugall
1.1	Updated version	05.06.2023	Oliver Portugall
2.0	Final version	12.06.2023	ISABEL Coordination Board, Oliver Portugall

DOCUMENT ABSTRACT

Deliverable D9.1 "Inventory of needs and potential" is the result of work performed within the eponymous task T9.1 of the ISABEL project. The task's purpose was to gather information that permits the compilation of a magnet technology roadmap in task T9.5 of the same WorkPackage.

TABLE OF CONTENTS

INTRODUCTION

In principle, D9.1 opposes two types of information collected from different target groups: the compilation of "needs" addresses the wider community of EMFL users irrespective of their field of expertise, whereas the evaluation of "potential" relies on the know-how of magnet engineers and a handful of specialists working in related fields. Despite this outward separation, neither subtask can be practically meaningful without taking into account the other's result: users should thus be guided in order to express demands that are technically feasible, while magnet engineers should be sensitized to user requirements that they may not anticipate. In order to satisfy both conditions, the original plan for T9.1 was to organize round tables and workshops bringing together users and magnet engineers in a joint discussion. Due to the COVID-19 pandemic, this idea had to be abandoned and was finally replaced by an entirely different approach.

1. Methodology

D9.1 is the result of a single integrated three-stage process that was organized as follows:

In stage 1, systematic interviews with EMFL in-house staff were performed to discuss their, and their external users', technical expectations in terms of magnet technology. By focusing on a target group with insider knowledge and hence the capability to analyze the feasibility of their ideas, this led to a first, overall realistic, compilation of "needs".

In stage 2, this compilation was assessed and expanded by EMFL magnet engineers, taking into account likely technical evolutions and their effect on performance limits and improvements. The result was summarized in a refined list of quantitative development predictions, including the principal criteria of scientific interest and technical feasibility in a long-term perspective. Apart from serving as basis for stage 3, this list represents an adequate description of "potential".

In stage 3, the list of possible developments was converted into a survey for external users, proposing different magnet configurations as well as compromises for competing parameters (e.g. maximum field vs bore size). Participants were asked to rate these suggestions by attributing up to three stars for properties that are considered useful (1 star), important (2 stars) or extremely important (3 stars). In an attempt to best guide the participants' choice, the survey was equipped with tutorial remarks explaining side-effects of certain parameter choices (e.g. oversized or long-pulsed magnets implying a reduced duty cycle). The possibility to express exotic ideas or add other remarks was accounted for by comment fields at the end of each section focusing on a particular group of magnets. Inversely, the survey was designed without mandatory parts. Several shortcuts to easily skip entire magnet categories were included so as to avoid forcing participants to spend time on questions that are irrelevant for their research.

With respect to its target group, the main survey was designed for participants with scientific-technical background and practical notions regarding the use of high magnetic fields. To reach out towards new user groups without such qualification, a contact sheet with simple general questions focusing on previously unexplored high-field applications was prepared. Unlike the principal survey, this contact sheet will serve in the long term to initiate the dialogue with primarily industrial partners to assess their needs in terms of magnet technology, and to explore the potential for new partnerships. The results of this process will eventually modify the landscape of "needs" but are currently to be translated into technical concepts and specifications.

2. Results

As in the survey, magnets are distinguished in 4 categories. Apart from standard user magnets these are mobile systems, magnets with specific geometry and magnets with specific time dependence. Categories are furthermore subdivided into groups based on technological criteria (e.g. DC magnets, pulsed magnets etc.). For each group, different parameter sets reflecting the EMFL facilities expected technical potential over the next decade are presented, together with the participants' rating. Figure 1 explains how to read the respective histograms.

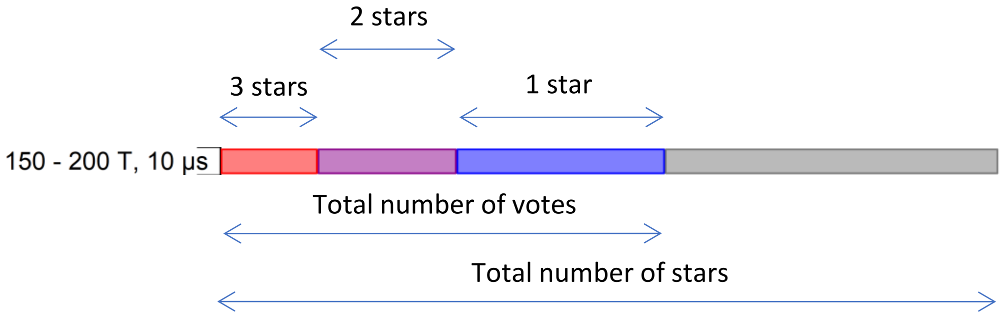

Figure 1: Organisation of histograms. The number of 1, 2 and 3-star ratings are represented by blue, violet and red bars that are stacked on each other. The extension of the three fields together thus represents the number of votes. In addition, a gray bar in the background shows the total number of stars attributed to each parameter set.

1.1 Standard geometry magnets at the EMFL facilities

Standard geometry magnets are the EMFL facilities' workhorses. With few exceptions, they are not adapted for specific purposes and serve a large variety of different experiments. Basic design criteria are maximum field and bore size, in pulsed systems also the field duration. In order to let participants consider quantities that are directly relevant for their work, specifications for bore size were split into sample space and cryogenic requirements that determine the size of cryostats. Apart from standard parameters a variety of special requirements regarding the quality of the produced field are proposed.

The ratings displayed in figure 2 below essentially confirm the relevance of parameter choices currently practiced in the EMFL facilities. In particular, there is no overly strong demand for larger sample spaces that would have to be counterbalanced by lower fields or an upgrade of energy and power supplies. Noise elimination emerges as an important issue for DC magnets, while pulsed magnets are subject to conflicting requirements of longer durations (in the ratings) and a higher duty cycle (in the comments). In the case of Megagauss fields, several comments mention the need for a better documentation of the existing experimental possibilities.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 871106

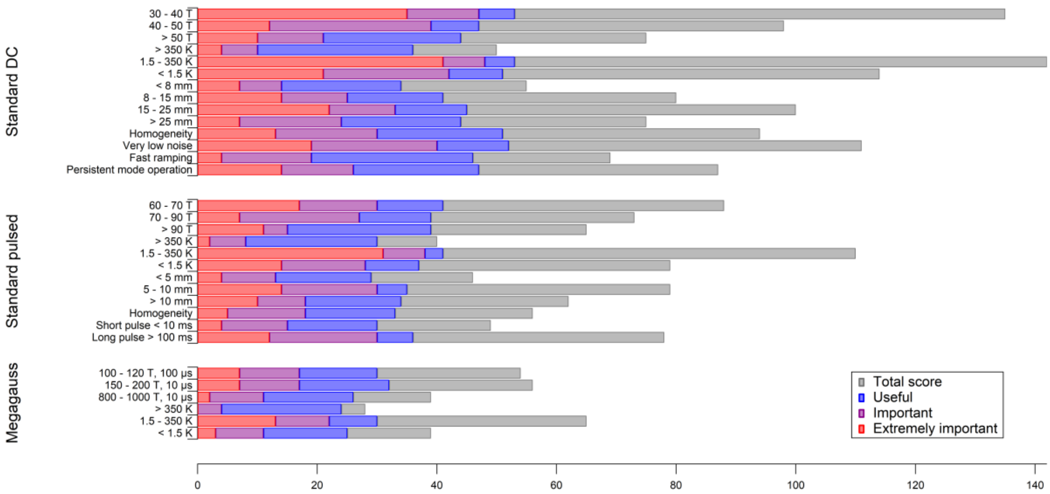

Figure 2: Parameter ratings for standard geometry magnets at the EMFL facilities.

1.2 Facility magnets with specific experimental access or geometry

This category concerns magnets for specific measurements requiring an oversized sample space or a particular experimental access to the latter. The construction of such magnets almost always implies a trade-off between maximum field and the desired geometry. In order to identify general trends for such compromises, different parameter combinations were proposed in the survey.

The level of specialization of magnets in this category explains the smaller participation in the votes. As a general tendency, the ratings indicate that disposing of the highest fields remains a priority for most users. On the other hand, it is pointed out in the comments that an opening towards other domains such as biology would require specific types of magnets, most notably for levitating or providing a large room-temperature bore.

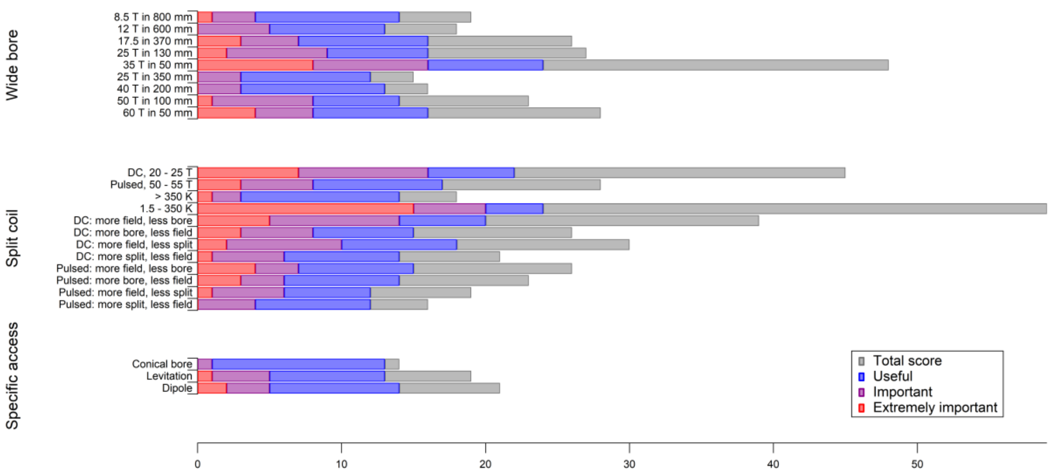

Figure 3: Parameter ratings for magnets with specific experimental access or geometry.

1.3 Facility magnets with specific time dependence

This category concerns high-field systems designed to provide particular field sweep rates, field plateaus, pulse shapes or other time dependences. As a rule, specific time dependences not only

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 871106

require the technical adaptation of magnets but also of power and energy supplies and hence a more substantial development effort and, most likely, capital investment.

As before, the category's specialization explains the small number of votes. On the other hand, magnet properties considered in this category are particularly interesting for NMR measurements and, hence, bear some interest for new applications as indicated by several comments.

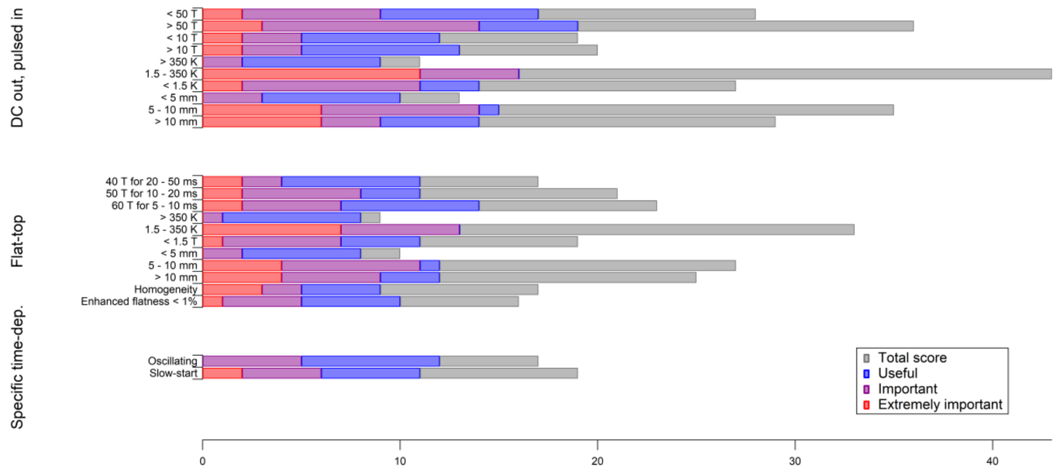

Figure 4: Parameter ratings for magnets with specific time dependence.

1.4 Mobile installations

Unlike magnets installed in the EMFL facilities, mobile installations can be shipped to, and combined with, other large infrastructures such as neutron, high-power laser, or synchrotron radiation sources. Mobile installations, therefore, not only consist of magnets but also power or energy supplies.

Despite a relatively small number of votes, the category's rating basically confirms the current EMFL strategy regarding mobile systems. In particular, there is no clear tendency towards smaller or bigger installations. The apparent interest in superconducting magnets represents an additional motivation for the development of high-Tc systems. EMFL is not currently involved in the design of conventional superconducting magnets that are the domain of industrial providers.

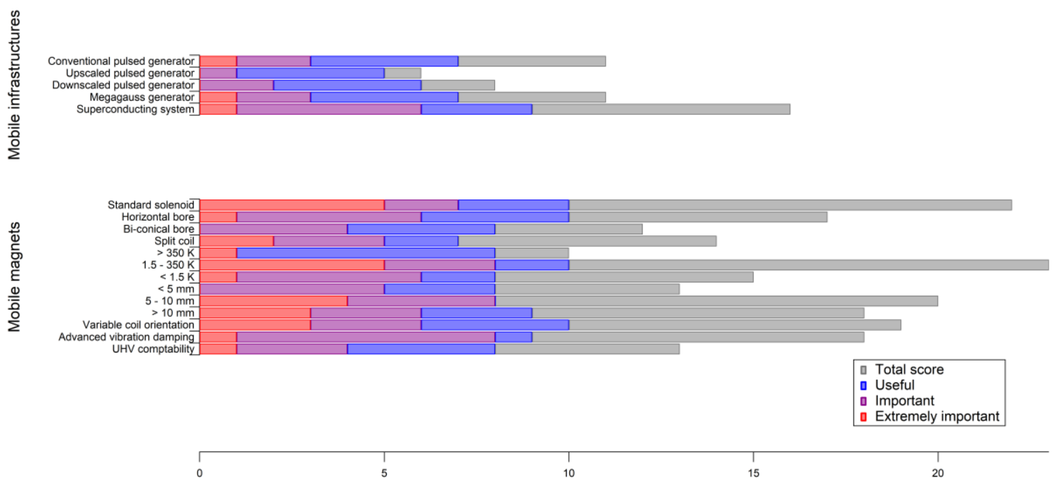

Figure 5: Parameter ratings for mobile installations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 871106

3. Conclusion

The survey's outcome endorses the EMFL-facilities technological strategy attaching priority to the development of all-around magnets for a large variety of different experiments. The most important design targets that emerge from the ratings are thus associated with basic properties such as maximum field or duty-cycle. Interestingly, this statement does not include large sample spaces and extreme temperatures that would imply wider bores and hence the deployment and handling of larger amounts of energy. In both cases, most survey participants tend to be modest, indicating a high degree of awareness of the technical difficulties and reflect a good communication between the EMFL facilities and their users.

Special requirements are put forward by some users, mainly in connection with specific experimental techniques. The call for low noise and high homogeneity in DC magnets, for example, refers mainly to nuclear magnetic resonance measurements that represent an important activity in some of the facilities. By comparison, few users express a clear need of magnets with special geometry or time dependence. To obtain a reasonable return on investment, the decision to develop one or more magnets of these categories should be left to the initiative of those EMFL-facilities where appropriate research projects exist.

In the present form, the survey results present a coherent picture but could still be improved by a wider participation. In order to enhance the statistical significance, the survey will, therefore, remain online for several more months. In parallel, occasions such as the EMFL user meeting will be used to stimulate direct discussions of new and exotic ideas that users may not be willing to express in writing.