



External Evaluation of the ATTRACT and PEARL Programs of FNR

Summary Report by the International Panel

April 2024

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1. Executive Summary

This evaluation, conducted by an international panel of experts focuses on the ATTRACT and PEARL programs, the flagship incoming and career initiatives of the Luxembourg National Research Fund (FNR). These programs aim to attract highly qualified researchers to Luxembourg, fostering the establishment of strong research groups and enhancing the country's research landscape.

The FNR, founded in 1999, operates as a key player in Luxembourg's public research system, with a current annual funding capacity of € 80-100 million. Its mission is to strengthen science as such and the link between science and society by supporting research activities. The ATTRACT program, launched in 2006-2007, targets early-career post-doctoral researchers, offering grants of up to € 1.5 million for Starting Investigators and € 2 million for Consolidating Investigators over a five-year period. The PEARL program, founded in 2009 to attract established researchers, awards large fellowships, currently funded with € 4 million each, over a five-year period.

The evaluation panel, commissioned by the Luxembourg Ministry of Higher Education and Research (MESR), assessed the programs' abilities to achieve their goals, accomplishments to date, appropriateness in the current ecosystem, and provided recommendations. The assessment was based on a 2.5-day site visit with nearly 50 interviews with different stakeholder groups, 12 pre-interviews, a Self-Assessment Report by the FNR, and a bibliometric study.

Despite challenges such as the small size and young age of Luxembourg's research system, the programs have significantly contributed to strengthening the research ecosystem. Since their inception, the ATTRACT program has seen 25 fellows, while the PEARL program has awarded 17 fellowships, both having a profound impact on Luxembourg's research landscape.

The bibliometric study revealed that both programs exhibited solid performance compared to ERC grant holders in Luxembourg. The fellows selected by the FNR under the ATTRACT program demonstrated superior publication performance compared to rejected applicants. For the PEARL program, results were a little less conclusive (also due to small numbers), with a high level of variance concerning the visibility and the impact of the individual researchers' publications.

The insertion of top talents through programs like ATTRACT and PEARL played a crucial role in internationalizing Luxembourg's research system during its development phases in the 2000s and namely the 2010s. These programs aimed to bring in highly qualified researchers from abroad and create critical masses in Luxembourg institutions, thus contributing significantly to the structural development of the research landscape. Both programs have successfully attracted top researchers, fostered interdisciplinary collaborations, and strengthened key research areas. However, as the research system matured, the role of these programs evolved. Changing framework conditions, operational challenges and transforming research cultures necessitate strategic adjustments and refinements for future sustainability and impact. While the initial focus – internationalization, talent attraction and critical mass – is still relevant, the programs are nowadays perceived differently by stakeholders: Some see a greater role for the more mature research performing organizations, and others view them as supporting innovation activities in a broader sense.

Both ATTRACT and PEARL have undergone numerous changes over the years, reflecting attempts to optimize the programs and adapting to evolving needs. The influx of new talent through ATTRACT and PEARL has facilitated critical mass and excellence in research fields, but the structural impact of each

new generation of fellows may diminish over time. Challenges persist, for example in aligning program goals with host institution traditions, particularly in senior leadership appointments. The low representation of female fellows and the difficulty for ATTRACT fellows in maintaining stable group sizes and resources after the funding period end pose additional challenges. The future of these programs is debated, with some suggesting their continuation under adapted framework conditions, while others question their necessity under the given conditions. The evaluation sheds light on the challenges and proposes solutions for the current framework conditions.

The ATTRACT program

The evaluation of the ATTRACT program reveals commendable achievements in bolstering Luxembourg's research landscape, with notable impacts on institutional capacities and international collaboration.

Performance of ATTRACT Fellows: The assessment indicates that ATTRACT fellows demonstrate high international standards in their research outputs. Notably, a significant portion of fellows at the University of Luxembourg (UL) attained full professorships, while a number of those in non-university institutes secured managerial positions. Fellows exhibited success in securing third-party funding, enhancing their visibility and impact. Though challenges with integration and funding sustainability exist, the program has achieved its goal of bringing excellent people into the country.

Capability of the ATTRACT Program: The program's main goal, to enhance Luxembourg's research in strategic areas by attracting promising talents, remains relevant. While the system has evolved, ATTRACT continues to play a crucial role in talent acquisition and research capacity building. However, concerns regarding funding sustainability, group budgets, and institutional commitments necessitate minor program adjustments.

Structural Effects of the ATTRACT Program: Notable structural impacts were observed, e.g. in UL units such as LCSB, C2DH, and the Department of Physics and Materials, highlighting strategic utilization of ATTRACT to bolster research capacities. Success stories underscore the program's potential to enhance research excellence and international visibility.

Selection and Administrative Procedures: The selection process is lauded for its fairness and quality, although improvements in host institution support and advertisement of the program are suggested. Feedback on administrative processes varies, with calls for increased transparency and reduced bureaucracy.

Conclusion: Despite evolving research landscapes, the ATTRACT program remains pivotal in nurturing research excellence and internationalization in Luxembourg. Continued adjustments and collaborations between FNR and institutions are essential to sustain its effectiveness in the future.

The PEARL program

The evaluation of the PEARL program indicates significant achievements in attracting leading researchers to Luxembourg and fostering strategic research initiatives.

Performance of PEARL Fellows: PEARL fellows demonstrate strong academic outputs, with a majority continuing their careers in Luxembourg. Success in acquiring prestigious third-party funding underscores the program's impact. While structural effects such as the formation of research groups and

strengthening of fields are evident, outcomes beyond academia, such as industry collaboration and spin-off creation are less well achieved (or documented) and require further scrutiny.

Capability of the PEARL Program: The program effectively attracts leading researchers, contributing to strategic initiatives and capacity building in Luxembourg. However, goal overload and complexities arising from joint appointments necessitate program adjustments to maximize impact.

Structural Effects of the PEARL Program: Notable impacts include the recruitment of top researchers and the establishment of strong research groups, particularly in strategic fields like clinical research, neurosciences or fintech. PEARL fellows have enhanced Luxembourg's competitiveness in international collaborations and interdisciplinary research.

Selection and Administrative Procedures: While the selection process is generally praised for fairness, concerns exist regarding lengthy procedures and increasingly unclear program goals over time. Ensuring equity, diversity, and inclusion in selection processes remains a notable challenge. One specific issue regards the Open PEARL as a specific selection and recruitment procedure: Experimentation with this promising variant introduced additional selection steps, extending timelines and potentially limiting candidate pools. The role of the Scientific Advisory Board is recognized as crucial and should be maintained in future iterations.

Conclusion: While the PEARL program has successfully attracted leading researchers and strengthened strategic research initiatives in Luxembourg, adjustments are needed to address operational challenges and ensure continued effectiveness. Clear communication, streamlined procedures along the Open PEARL principles, and strategic alignment with national priorities are essential for sustaining the program's impact.

The Panel suggests the following recommendations:

Recommendation 1

Keep both ATTRACT and a modified PEARL in the FNR funding portfolio.

Recommendation 2

The FNR should put the focus of both programs on scientific excellence and impact as the top funding criterion and research goal and treat other important topics as second-tier goals and criteria.

Recommendation 3

The FNR should be aware that increased administrative control does not, in general, increase the performance of their fellows and that new administrative measures should only be implemented if absolutely necessary. It should also take care that administrative processes during the funding period are highly consistent over time and fellows but, at the same time, display enough flexibility to be able to respond to the individual needs of fellows. More effort should be directed towards the announcement of open ATTRACT and PEARL positions and on international marketing of the location.

Recommendation 4

Keep ATTRACT in its current shape as an incoming program. For the individual grants, it is advised to increase their financial volume due to two reasons: firstly, to re-establish the original real value of the ATTRACT funding; secondly, to allow the possibility of payment of overheads to the host institutions.

Recommendation 5

The FNR and the host institutions should look for ways how the latter might support highly successful ATTRACT fellows through a minimum basic endowment after the end of the funding period.

Recommendation 6

The FNR should further develop PEARL—largely based on the Open PEARL model—as a well-endowed, clearly shaped funding line for rare strategic placements of top-caliber scientific researchers and their teams. The Panel recommends that PEARL should be open for foreign and Luxembourg-based candidates and coupled with a senior career step. It should follow a clear and faster selection process in accordance with the highest international levels of quality assurance based on scientific merit and potential as key criterion.

Recommendation 7

The FNR should increase the maximum financial volume for a PEARL fellowship to equalize inflation losses and to provide some overheads to the host institution. FNR and the RPOs shall negotiate an open and transparent long-term, tripartite, and mutually binding model contract. Such a contract shall also allow for one clear (main) affiliation per PEARL fellow. The SABs should be continued.

Recommendation 8

FNR and the RPOs should further develop incentives and criteria to help increase the number of female candidates. In addition, efforts should be taken to support highly qualified partners of new recruits from abroad.

Recommendation 9

The FNR should develop a more transparent and broader SMA mechanism that takes institutional strategic fit stronger into account without compromising the focus on scientific excellence. In addition, the relevant stakeholders should organize townhall-style meetings to discuss priorities to be operationalized and the instruments to implement them.

Recommendation 10

FNR shall re-establish and increase networking among ATTRACT and PEARL fellows and build up / enlarge instruments to increase the leadership potential of the former. These activities should be open to selected guests from outside (incl. industry) to increase the potential for knowledge transfer, cooperation and sponsoring.

2. Subject of the evaluation

Subject to the evaluation are the two main career programs—ATTRACT and PEARL—of the National Research Fund FNR. The aim of these long-standing programs is to bring highly qualified researchers to Luxembourg to set up strong research groups. The programs include incentives for Luxembourg research institutions as well as provisions for tenure or comparable career track (ATTRACT) or leadership positions (PEARL) at the University of Luxembourg (UL) or at one of the other research performing institutions, namely the three Luxembourg Research Institutes (LIST, LIH, LISER, designated as “LIs” in the report). In the following report, these four institutions are collectively summarized under the abbreviation “RPO” (research performing organizations). The evaluation has been commissioned by the Ministry of Higher Education and Research (MESR).

This report contains the main findings of the international evaluation panel (henceforth: the Panel) regarding program implementation, performance of the awardees and impacts of the two programs, followed by recommendations. The findings are based on numerous interviews, a Self-Assessment Report by the FNR (SAR) and a bibliometric study.

The Luxembourg National Research Fund (FNR)

Established in 1999, the FNR is the dominant research funding source and therefore a main player in Luxembourg’s public research system. The fund operates under the aegis of MESR. The FNR’s mission is to “support and coordinate activities to strengthen the link between science and society and to raise awareness for research” (SAR, p. 9). The FNR operates as a public institution under a four-year contract under legal capacity with full administrative and financial autonomy. The FNR’s governance structure includes a Secretary General / CEO, a Board of Trustees responsible for strategic decision-making and oversight of the fund’s activities, a Government Commissioner, and a Scientific Council composed of international experts.

The FNR’s budgets and scope of activities have been subject to strong growth since the beginning of the funds’ activities. Compared to the size of the country and its researcher population, the FNR—with a current funding capacity of € 80-100 million per year—is among the best-endowed public research funders in Europe. In 2023, the fund’s executive office has a staff size of 37. The FNR has a range of funding instruments, including grants for individual researchers (which, amongst others, include the ATTRACT and PEARL programs), project and program funding, and institutional support programs. In 2024, the FNR’s portfolio includes about 25 funding instruments, of which 16 are based on project funding. The annual worth of contracts awarded between 2018 and 2021 was approximately € 234 million.

One of the main goals of the FNR and its instruments is to strengthen Luxembourg’s Research and Innovation (R&I) system at national and international levels by attracting excellent scientists to the country. The programs’ objectives included fostering personal and career development, strengthening Luxembourg’s research ecosystem, and generating impact in strategic areas. The two most important instruments for this are the PEARL and ATTRACT programs, which are subject to this external evaluation.

The ATTRACT program

ATTRACT was established in 2006-2007 amidst international changes in research recruitment and employment practices. The program is aimed at early-career, post-doctoral researchers (two to eight years after PhD) not yet established in Luxembourg who demonstrate the potential to become leaders in

their field of research. The objective is to recruit outstanding young researchers from all over the world to develop their independent research group in key research areas. The program offers two funding tracks: *Starting Investigators* (postdoc & junior researcher level) can receive up to € 1.5 million per fellowship, while *Consolidating Investigators* (established researcher level) can receive grants of up to € 2 million. The funding duration is five years for both variants. The fellows are expected to establish and manage their research groups independently. Additionally, the program provides tenure or tenure-track opportunities (since 2013; cf. SAR, p. 28), relocation assistance, and personal leadership coaching.

ATTRACT calls are launched annually, with a rigorous evaluation process involving pre-proposal and full proposal stages, peer review and interviews. The applicant's pre-proposal must be submitted jointly with the host institution and is assessed for consistency with the institutional and national strategic priorities by a *Strategic Merit Assessment* (SMA). Following a remote evaluation of the full proposal by thematic experts, the ATTRACT standing panel invites the candidates to an interview and provides a funding recommendation. The final selection is then made by the FNR Board. Funded projects need to submit annual progress reports, take part in an interim evaluation as part of the career development plan and provide a final report.

The program has seen 17 calls (SAR, p. 24 ff.) since its inception, with 25 fellows recommended for funding (of which 24 accepted) in the years 2007-2022. The overall success rate of applications is 28%, with a total awarded budget of € 39.5 million. UL has been the most successful institution with 17 ATTRACT fellowships, and thematic foci mainly in material and physical sciences, biomedical sciences and in the humanities. LIST had attracted four candidates in material, physical and environmental sciences, and LIH three in the biomedical sciences. No applications from LISER have so far been successful. Of the 24 fellows, six were females and 18 males. The program has contributed significantly to Luxembourg's research landscape, with nearly all selected fellows remaining active in academic research. Nearly all still work in Luxembourg, with many in full professor or other senior positions.

The PEARL program

PEARL seeks to draw established and internationally recognized researchers to Luxembourg. The objective is to attract leading researchers to develop a research program in areas of strategic importance to the country with the potential to generate long term impact and to strengthen the national research ecosystem. PEARL candidates must not be employed at a Luxembourg-based institution at the time of a call's launch. Through the recruitment of outstanding scientists in strategically important areas, the PEARL program aims to accelerate the development and strengthening of Luxembourg's national research priorities. There are two paths to funding: a *traditional* PEARL fellowship, which focuses on an individual and their research ideas, or, since 2016, an *Open* PEARL fellowship which focuses on the goals of an institution, who also selects the candidate. Since 2017, the two PEARL fellowship variants are endowed with, respectively, € 5 million and € 4 million. A maximum of two PEARL fellowships are available each year. The fellowship is based on a five-year agreement between the host institution and the FNR, and a ten-year "expected" (SAR, p. 40) timeline for the research program.

For the traditional PEARL, the selection process consists of a pre-proposal, evaluated in the SMA phase by the PEARL standing panel. The pre-proposal is focused on institutional strategic fit and commitment. The longer full proposal is part of the interview phase and focuses on the candidates and their projects, culminating in an interview with the thematic and standing panel. The selection process of the Open PEARL track has one additional step, as the program's main aim is "to fill a strategic vacancy through a competitive call [...] to allow a focus on advancing an important strategic niche in Luxembourg" (SAR,

p. 41). The two steps of the traditional PEARL process are supplemented by a candidate search and a pre-selection process in which the host organization searches for suitable candidates.

Between 2009 and 2023, 17 fellowships have been awarded with 45% acceptance rate, with only two female fellows over the lifespan of the program. The greatest number of accepted applications have been submitted by UL (9), followed by LIST (6), and LIH and the Laboratoire National de Santé (LNS, jointly with UL and LIH) respectively (1 each). A few PEARL fellows have more than one affiliation. As in the ATTRACT program, the fields of material sciences and physics, biomedical sciences and humanities are strongly represented. In addition, ICT and space research account for another five PEARLS. As for ATTRACT, no fellowship has been awarded to LISER so far. In 2023, twelve PEARL fellows were still in the country and 14 of the 17 groups still existed in Luxembourg.

3. Contextual information: The Luxembourg research landscape

As a small country with only 660,000 inhabitants in the middle of Europe, Luxembourg is characterized by the great diversity of its population and its labor market (as of 2023, 47% of residents are non-Luxembourgers). As a seat of central service industries and European institutions, the country serves as an important hub and has undergone a long and successful structural transformation. Wealth, institution-building and international openness also characterize the Luxembourg research and innovation system. Public R&D investments are high (approx. 0.6% of GDP, SAR, p. 11). In recent years, the Luxembourg research and innovation system has undergone significant developments, particularly in response to the challenges and opportunities posed by the country's economic landscape and societal needs. Strong efforts and investments have been made to transition away from the steel industry and to diversify beyond the finance industry, with emphasis on sectors such as material sciences, ICT, space technology, and biotechnology but also digital humanities.

It was only at the turn of the millennium that the country began to invest in its public research and innovation system, with UL founded in 2003. Aside from the university and its three interdisciplinary centers—the Interdisciplinary Centre for Security, Reliability and Trust (SnT), the Luxembourg Centre for Systems Biomedicine (LCSB), and the Luxembourg Centre for Contemporary and Digital History (C²DH)—there are three main public Luxembourg research institutions: LIST, LIH and LISER (LIs). These are the main contributors to the research and innovation ecosystem.

These intensified efforts led to the development of Luxembourg's National Research and Innovation Strategy (NRIS)¹ in 2017, which has the main objective for Luxembourg “to become a sustainable, knowledge-driven, diverse and trusted digital society” by 2030 (p. 9). The four main pillars of the strategy are: *21st Century Education, Sustainable and Responsible Development, Personalized Healthcare, and Industrial and Service Transformation*. By 2023, Luxembourg invested around € 470 million in their research and innovation system, which is the highest public budget allocation for R&D per person in the EU.²

Collaboration with various stakeholders is key, exemplified by partnerships between public RPOs and private enterprises. State actors play a crucial role in shaping the research and innovation agenda in Luxembourg. Government agencies and ministries, such as the Ministry of Higher Education and Research or the Ministry of the Economy, provide funding, infrastructure, and policy support to promote research excellence, foster innovation, and stimulate economic growth. Additionally, state-driven

¹ <https://www.researchluxembourg.org/en/research-landscape/national-research-innovation-strategy/> (accessed March 11, 2024)

² <https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230804-2> (accessed March 8, 2024)

initiatives, such as the FNR, demonstrate a commitment to mission-oriented research and strategic investments in priority areas of national interest.

Challenges for the Luxembourg R&D policy, as well as for its institutions, include the small size and the young age of the research system, the strong influence—and at the same time—the very limited small home base of the relevant institutions. The latter makes it sometimes difficult to build up critical mass but also to reach out to a wider geographical area. The institutions must answer numerous and pressing national needs, from training of teachers to provision of health services. The expectations of state (as well as private) actors can be diverse, dense, and frequently demanding.

Finally, Luxembourg lies on a cultural fault line between the French and the German (higher education and innovation) systems, creating the need to merge differing experiences and expectations of various actors in a small, emerging, and open landscape.

The Panel has been informed in an open and transparent way about the context and structural issues, but also about remarkable success stories in dealing with them.

4. Assignment of the evaluation panel

MESR commissioned an international panel of experts to execute the assessment. The overall aim of the evaluation is to provide MESR with an external and independent assessment of the ATTRACT and PEARL programs to understand how far each of the programs—in their current forms—has achieved its goals and to provide recommendations for the future development of both programs. Hence, the Panel has been asked to assess the following general aspects:

- Assess the capability of the programs to reach their defined goals.
- Take stock of the accomplishments of the programs to date.
- Assess the appropriateness of the programs with regard to the current level of maturity of the ecosystem and its future developments.
- Provide recommendations for the further development of both programs.

The Panel—appointed by MESR—is composed of experts from the fields of life sciences and medicine, physical & material sciences, ICT & computer science, social science and humanities, and research funding.

Members of the panel (henceforth collectively called the “Panel”) are: Liselotte Højgaard (panel chair; University of Copenhagen and DTU), Barbara Caputo (Politecnico di Torino), Peter Fratzl (Max-Planck-Institute of Colloids and Interfaces, Potsdam), Caroline Heckman (University of Helsinki), Patrick Llerena (University Strasbourg), Michael Stampfer (WWTF) and Christian Thomsen (TU Berlin). The panel is supported by a secretariat, provided by the contractor WWTF GmbH.

The panel’s assessment is based on a SAR provided by the FNR, a bibliometric study, and single and group interviews more than 60 persons conducted in advance or at the site visit in Luxembourg (19-21 February 2024). All interviews were confidential. The panel's assessment was carried out independently and was not bound by instructions from MESR or the FNR.

5. Upfront evidence: Summary of the bibliometric study

A bibliometric analysis was contracted by WWTF GmbH and carried out by Anton Geyer (inspire research) and Juan Gorraiz (University of Vienna) to support the Panel’s assessment.

The study analyses the publication output of funded versus rejected applicants of the PEARL and ATTRACT programs since the start of the programs up to the call year 2018³ in a four-year publication window after the start year of the (assumed) fellowship period. The publication output of the funded PEARL and ATTRACT fellow in the respective publication windows was also compared to the publication output of ERC grant holders with an affiliation in Luxembourg who started their ERC grant between 2008 to 2018. The analysis uses normalized bibliometric indicators (i.e. across fields of research, document types and publication years) to ensure robustness of the comparison of publication output based in varying scientific disciplines and moving time windows of publication. In total, 20 PEARL applicants (ten funded, ten rejected), 71 ATTRACT applicants (18 funded, 53 rejected) and eight ERC grant holders with an affiliation in Luxembourg were included in the bibliometric analysis.

For the ATTRACT program, all evidence points to the fact that the fellows have been carefully chosen by the FNR. All normalized bibliometric indicators point to a far better publication performance of the group of funded applicants compared to the group of rejected applicants in the years following the funding decisions.

For the PEARL program, the analysis shows inconclusive results regarding whether the funded applicants performed better overall than the rejected applicants. There is a high level of variance concerning the visibility and the impact of the individual researchers' publications within the groups of funded and rejected PEARL applicants. The findings for the PEARL program suggest that criteria not related to publication output and performance may have played a significant role in the original selection process.

The average values for all normalized bibliometric indicators for the successful ATTRACT and PEARL applicants are well above the expected values and well above the average values for all publications from Luxembourg published between 2008 and 2022.

The bibliometric comparison of the group of ATTRACT and PEARL fellows with the group of ERC grant holders in Luxembourg points to an overall somewhat lower performance of the ATTRACT and PEARL group. Given the competitiveness of ERC funding, this result is expected and there is thus no indication that the ATTRACT and PEARL programs did not perform well.

Overall, the bibliometric study shows solid results for the ATTRACT and PEARL programs and that the FNR performed well in selecting the fellows.

6. Insertion of top talents: common elements of the programs

Both programs were set up at a time when the research system in Luxembourg was in its early development phase. The programs' introduction coincided with the founding of UL in the early 2000s, and various restructurings and mergers in the RPO sector. In many of the interviews with stakeholders, the Panel was presented with accounts that both programs were important interventions at that time to internationalize the Luxembourg research system, to bring in highly qualified researchers from abroad, and to create critical masses in institutions in Luxembourg. Hence, for at least some time, both programs have been pivotal in developing the research system in Luxembourg and have had visible structural effects on the system. However, according to many interviewees, now that structures have been largely established, each generation of incoming researchers might yield less structural effects and diminishing returns.

³ As a four-year publication window after the funding started is the data basis, no fellowship after the call year 2018 could be included.

Therefore, as the research system in Luxembourg matured, the role of the programs has changed. Institutions have further developed their specific portfolios, career models and organizational features. Nevertheless, the development process towards an established institutional research culture is not fully completed: the position of Luxembourg between the distinctively different German and French systems still leads to mixed practices and different perceptions (which some interviewees also find attractive); and some of the RPOs are still in the process of optimizing their structural set-up. Nevertheless, the Luxembourg RPOs have gained a considerable degree of maturity. Therefore, both the perception and the function of ATTRACT and PEARL have shifted and diverged for some of the leaders in the research system: while some organizations expect the programs to attract scientifically excellent researchers from abroad, others see the program as supporting innovation activities in a broader sense. Some of the RPO representatives were very critical regarding the overburdening of the programs with an increasingly large set of criteria and requirements.

Individual leaders of research institutions also raised the possibility of redirecting the program budgets to base funding of their organizations, in order to directly hire more researchers. Some institutions stated that they had become more confident in selecting their own high-level researchers, which increasingly came into conflict with the stakes the FNR had and still has in the program. With respect to PEARL, interviewees provided a number of ideas on how the programs could be continued to better fit the needs of the institutions. Some interviewees also raised the question if both programs are needed at all and whether they should be entirely abandoned. Opinions diverged—even in the same peer group—in the question whether the system has reached sufficient maturity to function properly without PEARL and / or ATTRACT.

Both ATTRACT—and in particular—PEARL were subject to change in the programs' set-up over the years. The FNR report lists ten program changes for ATTRACT since 2010 (SAR, p. 27f.) and six evolutionary steps for PEARL since 2013 (SAR, p. 46f.). This adds up to a considerable number of changes, with a different goal. While the modifications in ATTRACT mainly aim at optimizing the program (e.g., through the introduction of tenure track), PEARL has been more subject to experimentation, as exemplified by "Open PEARL", combined ATTRACT / PEARL applications by the institutions, multi-affiliation PEARLs, or a "dual PEARL" for two closely related researchers. This report will return to some of the changes in the chapters on the individual programs. The general observation here is that PEARL as a major structural and career-centered intervention has been difficult to design and to manage, both for the FNR and for the RPOs.

ATTRACT and PEARL are both laden with expectations, goals, and criteria, mainly due to shifting policy discourses, the broadening mission of the FNR, "the broad definition of excellence" (SAR, p. 40), and its ambition to be among the most progressive funders across Europe. As its objectives for PEARL, the FNR states: "PEARL fellows and their groups should strive for a broad range of structural impact, in line with the FNR's goals for research excellence (Scientific Impact, Public Outreach, Teaching/Training/Mentoring, Societal Impact, Economic Impact, Shaping the Research System)." (SAR, p. 40). This is a great deal to simultaneously achieve within a single program, and potential conflicts lie within these goals. Moreover, FNR does not appear to have followed and monitored most indicators for these ATTRACT and PEARL goals in a structured way. At least the self-presentation (SAR, pp. 34 ff., 48f.), remains rather superficial and anecdotal compared to the importance attributed to the objectives.

Another gap between aspiration and delivery is the gender aspect. The number of female PEARL and ATTRACT fellows is low, with two of 17 funded PEARL fellowships and six out of 24 funded ATTRACT fellowships. In addition, the number of female applicants is also low and not easy to influence by the FNR. As one of several measures taken, the requirement for gender parity in the ATTRACT application process (SAR, p. 34) in 2020 has been an important step but was accompanied by a decrease in overall

application numbers. Further measures should be developed together with the RPOs to increase the number of female applicants and fellows.

The Panel acknowledges that the Luxembourg research system has reached a high degree of maturity, though not to the level at which both programs should be abandoned. Therefore, the Panel recommends continuing both programs, though under the following two conditions: (1) specific framework conditions need to be adapted, and (2) in particular for PEARL, the program itself should be changed. When regarding the future of the two programs, it should be noted that PEARL and ATTRACT account for 10.6% of the cumulated FNR funding expenditures (approx. € 100 million vs. € 946 million since 2006; cf. SAR, p. 15). The actual budget share is therefore significantly smaller, as the two programs have remained stable in grant size and number of fellows granted, while the overall FNR budget has grown steadily.

A main challenge both for the system and individual fellows remains the question of how a stable group size and/or sufficient resources for infrastructure can be maintained after ATTRACT and PEARL funding runs out. Many interviewees addressed this issue. Not only are institutional commitments for resources after the funding period difficult to obtain, but other FNR instruments like CORE are not sufficiently flexible to provide a seamless transition from ATTRACT and PEARL to other third-party funding. Furthermore, some rescaling of funding after ATTRACT and PEARL is necessary to maintain the overall system and to have free means for future opportunities. The first generation of top-level scientists attracted to Luxembourg are soon about to retire, and if the ATTRACT and PEARL programs are not continued this may lead to a loss of the excellence level the country has built up so carefully. The question is how to design such a mechanism that manages the balance between retaining resources to keep the top talent in the country and releasing resources to allow for a healthy turnover of senior personnel.

7. Key Assessments for ATTRACT

Performance of ATTRACT Fellows

Based upon the evidence provided to the Panel, the overall output of the ATTRACT fellows can be said to meet high international standards. 50% of ATTRACT fellows at UL who started before 2018 became full professors. (It is currently too early to assess those fellows starting after 2018.) Most of those employed at a non-university institution—who cannot be awarded with professorships—received decent managerial positions in their institutions. Overall, the institutions consistently managed to keep the fellows for a long-term career. Only two fellows went abroad, receiving a full professorship in their new institutions. The ATTRACT fellows were also successful in acquiring further third-party funding at FNR (e.g., within the FNR's CORE program). Except for fellows from the humanities, in which it seems difficult to acquire third-party funding via CORE due to its orientation along the national priorities, nearly all the fellows have been successful with further applications at the FNR. More infrastructure oriented ATTRACT projects were also more successful in acquiring FNR third-party funding. A good proportion of fellows also received funding from European-level programs. Three of the fellows received ERC grants.

A direct comparison to researchers without an ATTRACT fellowship was not possible due to the limited number of fellows in the sample, a lack of respective data, and methodological problems of matching comparable researchers with similar profiles. What can be said based on the bibliometric study is that ATTRACT fellows display a considerably higher level of visibility, impact, and international collaboration in terms of publication output compared to that of the rejected ATTRACT applicants.

Based on the accounts provided by the interviewees, ATTRACT fellows have been successful in establishing research capacities through the creation of new research groups, though such accounts are difficult to quantify. It was stated that it is easier to recruit personnel for the groups due to the high prestige of the fellowship. However, while ATTRACT provides a good starting package, inflation may produce difficulties in maintaining the group further down the line. Given the structural differences between the institutions hosting ATTRACT fellows (organizationally, legally, etc.), some institutions will be better able to absorb the decreasing funding and thus provide better conditions for sustaining the group. As an example, LIH has reported that it can sustain the groups after funding, while such a solution might be more difficult in the university context.

As a person-oriented program (i.e., the funding is around a particular researcher), the host institution cannot be required to maintain the group upon the departure of the funded fellow. Given that most of the ATTRACT fellows remained in Luxembourg, the departure of individual fellows to an institution abroad did not pose a structural problem to the system.

Overall, ATTRACT fellows appear well-integrated in their host institutions and have also established themselves in the national research landscape. This has improved significantly over the lifetime of the program. Early ATTRACT fellows had mixed experiences in terms of integration. Some already received full support during the application phase from their host institutions, while others struggled with their host institution's lack of familiarity with the funding scheme (lack of clearly defined career perspectives, high teaching loads, no support for preparing the proposal, no entitlement for the supervision of students). However, the fellows felt their concerns were heard by the FNR, leading to significant improvements of the situation.

In terms of teaching, ATTRACT fellows have reduced teaching obligations in the first three years (SAR, p. 35) but in single cases the Panel heard that obligations for teaching are still too high. The question was also raised whether a reduction for three years is enough within the framework of an ATTRACT fellowship, as the research group should also continue to receive a substantial amount of attention.

In terms of supervision, ATTRACT fellows automatically receive ADR at UL once they become assistant professor (SAR, p. 35). This is crucial for the supervision of students and PhD candidates in their own group. ATTRACT fellows account for the supervision of more than 100 doctoral candidates. The Panel considers these activities as very important and impactful with regard to the future of Luxembourg as a research location.

Capability of the ATTRACT Program to Reach its Defined Goals

The main goal of the program according to the FNR is "to boost Luxembourg research in strategically relevant areas, by bringing highly promising research talents from abroad" (SAR, p. 21). The program was created at a time when the system in Luxembourg was very young, and its structures and capacities were not yet fully established. Coming at a relevant timepoint, it was a well-designed and -operated policy intervention with a clear goal. It also received a relevant logic of intervention and was met with a high absorptive capacity of the involved RPOs. In the interviews, the program's achievements in building up capacities at Luxembourg RPOs and bringing "fresh water in the pond" to keep the excellence level a constant addition of the best talents to the small research ecosystem in Luxembourg were highly regarded. For the current situation in Luxembourg, its basic intervention mechanism and its goals are still well appreciated by fellows and representatives of the RPOs alike.

However, the research system has further developed over the years. The strong growth phase of the system has transitioned into a consolidation phase. Most of the strategically relevant fields based on

national priorities have been occupied by highly qualified researchers and their groups. Topics that were emerging at the time have since been institutionalized in institutes, centers, or departments. The retirement of the first generation of Luxembourg researchers in the coming years means that the issue of managing growth has been and will, in part, be replaced by that of natural turnover and further sharpening of institutional profiles. Accordingly, the ATTRACT program must be seen within this new and changed context.

Despite these transformations, most interviewees still regard the program as highly relevant and of high need. Only very few voices would opt for abandoning the program entirely. However, some RPO representatives reported challenges and hence the need for adjustments to the program. According to some interviewees, the program requires substantial co-funding on behalf of the institutions to keep the fellowship attractive. Notably, overheads to the institutions are not included. Concerns were raised about the contractual binding of the commitments provided by the hosting institutions after the funding period. It was reported that not all RPOs fulfilled their commitments in all cases. The decreasing value retention of the provided funding may place the program at risk of becoming unattractive, while also placing the funded fellows at risk of having insufficient resources to pursue ambitious research goals.

The introduction of a tenure track requirement for an ATTRACT fellowship in 2013 was a crucial step in the development of the program. It greatly contributed to the attractiveness of the program for top level junior researchers from abroad. Some voices from the interviews, however, raised the issue that Luxembourg does not have a culture of denying tenure to people once they are on the track. Thus, it is possible that a few researchers might occupy positions that could be assumed by even better qualified researchers. The Panel has no indication that this is the case for ATTRACT fellows, nor that this is an issue for which this evaluation can provide a meaningful input. However, the FNR can support decisions made by the institutions in the tenure process by taking them into account when setting requirements for the funding and the evaluation processes.

Considering all the evidence provided, the program's goals are still valid and relevant in today's changed context, and they will continue to be so in the foreseeable future. The reasons are twofold. Firstly, the structuring and establishment of public research in Luxembourg has advanced far but has not reached its final state. This is both because the system is still very young *and* because such a task is never ending, due to factors like retirements, restructuring as well as new scientific and technological challenges. Secondly, Luxembourg is and will remain a distinctly small research system, with the need to remain very open to the outside world. Active talent search and their integration shall be safeguarded in different ways and on different career levels. The competition for top talent will remain a challenge for Luxembourg in the times coming. The ATTRACT program is an important cornerstone to deal with this challenge.

Structural Effects of the ATTRACT Program

This report considers the structural effects of the program in two contexts: effects and impacts in the academic context, and in a wider societal, political and economic context.

Of the overall 24 ATTRACTs, UL has managed to win 17. The Panel found that the ATTRACT program had remarkable impact on three units of UL: LCSB, C²DH and the Department of Physics and Materials. At the latter, there are eight ATTRACT fellows among the 17 professors of the Department. Additionally, there is also one PEARL fellow there, such that both programs together account for more than 50% of the professors there. Hence, the Department of Physics and Materials has made very strategic use of

ATTRACT (and PEARL) to expand its research capacity. A good proportion of the Department's ATTRACT fellows also became full professors, while all others made the career step to associate professor.

At LCSB, four of the 16 current professors are ATTRACT fellows, while an additional three are PEARL fellows. Thus, a total of seven of the 16 professors were recruited through FNR programs. LCSB also hosted another two ATTRACT fellows who have since gone abroad for other positions. Careerwise, all ATTRACT fellows at LCSB have since become full professors.

Given its size, the C²DH at UL has also made good use of ATTRACT (together with PEARL). Of their 13 professors, one was recruited through ATTRACT, and another one through PEARL, such that 25% of the current professors arrived in C²DH through FNR programs. These cases exemplify one feature of the *additionality* of ATTRACT, beyond the quality of the individual research.

For all other institutions (LIST, LIH) and further units at UL, the structural impact on critical mass through the ATTRACT program is not given.

The success of LCSB, the Department of Physics and Materials and of C²DH demonstrates that if the institutions and their subunits coordinate well with the FNR programs, such programs can be an extraordinary leverage for research excellence, the building of critical masses and international visibility. The FNR should take these examples as role models for the further development of the program(s). Interviews with ATTRACT fellows and RPO leadership show that several top talents were attracted by strong research environments.

The FNR reports (SAR, p. 35) that, in addition to the 24 funded ATTRACT recruitments, another 16 unsuccessful applicants have moved to Luxembourg. This is an additional positive effect, although the Panel does not have information on how many researchers in both categories would have been hired regardless of the ATTRACT program. The "pull effect" as one form of immediate impact seems to be given but also limited: "[... FNR] data since 2017 show that from the 29 candidates who applied since 2017, only 10 [...] were already under an employment contract at the timepoint of application." (SAR, p. 32). This is remarkable, even if the majority of those funded afterwards were not among those hired upfront.

For international collaboration, anecdotal evidence shows that various ATTRACT fellows successfully participate in European projects and networks. However, the Panel was not provided by FNR with comprehensive data in the SAR. It lists only several MSCA, EMBO, and a few other fundings (SAR, p. 36). No monitoring was presented for non-FNR funding. FNR only reports its own funding, which includes also the successful bi- and multilateral funding arrangement INTER. The evidence for knowledge transfer and socio-economic impact—two important FNR goals—is remarkably thin and fragmentary. The funding agency seems to have no monitoring in place and reports only some very diverse examples (SAR, p. 36) for technology transfer, cooperation and societal impact. Despite adding a few more examples, the interviews were also not very conclusive in that respect. As the Panel sees ATTRACT as an instrument to strengthen scientific research in Luxembourg, it is not overly concerned with such omissions. However, what is stated as objectives should also be monitored, measured and documented.

An external evaluation was carried out for ATTRACT in 2017. The results are highlighted in the SAR (p. 29). The evaluation resulted in a very positive overall assessment and included several recommendations that can be summarized under the following points: sustainability beyond the funding period, increasing international awareness and visibility of the program, tracking unfunded applicants, adjustments to the review process in terms of transparency and efficiency, increasing the proportion of women and looking at the role of social sciences and humanities.

Selection and Administrative Procedures

The selection process can be described as fair to the candidates and of high quality. In general, the fellows had high praise for the selection procedures of the FNR in terms of its quality and appropriateness. They were perceived as rigorous but fair, merit-based and open. The fellows appreciated that the standing panel posed challenging but highly informed questions in the hearings. Similarly, the applicants appreciated that the assessments adopted a broader view and did not merely focus on bibliometric indicators. The FNR should take care to uphold the high quality of the procedures in the future. The organization of the selection as a two step-process is lengthy but was not subject to criticism in the interviews. A further extension of the selection process, however, should be avoided in any case. Interviewees reported the greater selectiveness of the RPOs in presenting ATTRACT candidates to the FNR as a positive development.

The support in the application process by the hosting institutions was perceived as somewhat inconsistent throughout the cohorts of fellows but has also improved over time. A clearer division of labor and better coordination between host institutions and FNR could further improve the process and provide more transparency for the applicants.

In terms of how applicants learned about the program, the Panel could not identify consistent channels through which this was accomplished. Very often, applicants learned about the program by chance or personal encounters with established researchers from Luxembourg. The FNR and host institutions should strive for more structured approaches in terms of advertising both the program and the open positions. In that respect, the Panel acknowledges the challenges for a rather small and young research location in making its name globally known to many potential candidates across many disciplines. The necessary extra effort should be considered, at least in areas in which critical mass in Luxembourg has already established.

Feedback on the FNR processes during the funding period was mixed. Some fellows reported inconsistencies on behalf of FNR in terms of requirements regarding evaluation criteria in their tenure process as well as on the use of the budget. FNR should improve its internal compliance mechanisms so that the adherence to agreements is transparent and easily assessed, even if there is change of personnel within the FNR. Other interviewees hinted at increased bureaucracy at the FNR in the administration of the fellowships.

The question if and how far the FNR should intervene in institutional requirements (such as high mandatory teaching obligations of fellows, different career promises) or balancing the structural differences between institutions (e.g., institutions with no teaching vs. the university with high teaching load) is difficult to answer for the Panel. On the one hand, the autonomy of the institutions must be respected; on the other hand, large imbalances between the situation of the fellows might negatively affect the impact of the program. Increased exchange between the FNR and the leadership of the institutions could be a soft measure to address these issues.

In terms of life beyond academia, fellows view Luxembourg as an appealing destination due to its high salaries and superior social standards, such as childcare and healthcare. ATTRACT fellows received assistance in relocating to Luxembourg, which they greatly appreciated. Additionally, both fellows and the FNR valued social networking events for and among the fellows. These events were largely canceled during the pandemic and have yet to resume.

8. Key Assessments for PEARL

Performance of PEARL Fellows

According to the evidence provided in the bibliometric study, in the SAR and in interview statements, the overall output of the PEARL fellows meets international standards. The bibliometric study shows (with low statistical significance) very good publication impacts, albeit somewhat less impressive than those of the ATTRACT fellow cohort. PEARL fellows have been very successful in pursuing an academic career in Luxembourg or abroad. About 70% of PEARL fellows continued their career in Luxembourg and took up leading positions in management in the Luxembourg research context. Those who left Luxembourg could by and large obtain important positions abroad. Although the percentage is higher than with ATTRACT fellows, the turnover is within an acceptable range.

PEARL fellows were also successful in acquiring further third-party funding at FNR (in particular, within FNR's CORE program). One PEARL fellow was also able to receive an ERC Advanced Grant. A direct comparison to researchers without a PEARL fellowship is not possible, again due to the limited number of PEARL fellows, lack of respective data, and methodological problems of matching researchers with comparable profiles.

Overall, the PEARL fellows have been successful in extending research capacities through the creation of new research groups. As a person-oriented program, the host institution cannot be required to maintain the group upon the departure of its PEARL group leader.

Other outputs such as patents and outcomes beyond large impactful consortia (see below) such as science-industry collaboration, or creation of spin-off companies are less visible from an external perspective. Neither the SAR nor the interviewees put a strong focus on science-industry interface. For the Panel it remained to a certain extent unclear whether this is due to lack of reporting or lack of activities.

Capability of the PEARL program to reach its defined goals

The PEARL program can be seen as successful, given the program objective: "Attraction of leading researchers that will develop a research program in areas of strategic importance to Luxembourg with the potential to generate long term impact and to strengthen the National Innovation System." (SAR, p. 40). Leading researchers have indeed been attracted to Luxembourg and several of them have already made contributions to the build-up of strategic initiatives or have been recently hired to senior strategic positions, such as taking space research to the next level (see below, and SAR, p. 46f.). At the same time, the PEARL program is also characterized by goal overload (see chapter 6), which may limit the impact of the venture to bring top scientists to Luxembourg. The ability of PEARL funding to allow for capacity building is widely acknowledged. Clear pre-existing strategies of the host institutions appear to have a beneficial effect on that ability. As reported in interviews, some parts / centers of UL and individual LIs appear to execute their strategies in a more concise way, allowing for PEARL fellows to use the substantial funding to build up strong research cores.

Joint appointments across two or more host institutions were originally seen as promising forms of integration into the Luxembourg system. However, in several cases, interviewees reported that the life of PEARL fellows has been complicated by such arrangements. The fellows had to comply with many different rules and regulations of the involved organizations, which diverted valuable energy from research activities. In addition, some PEARL fellows from LIs wished to obtain a more complete UL affiliation in parallel but learned only later that they would only be eligible for an adjunct professorship.

Structural Effects of the PEARL Program

Interviews with PEARL fellows and RPO leadership showed that various top researchers were attracted to Luxembourg by the existence of strong research environments or the opportunity to expand them. As with ATTRACT, several research fields could be successfully strengthened across institutions. This is exemplified by LCSB at UL with three PEARL fellows and their strategically important projects, and the UL Faculty of Language and Literature, Humanities, Arts and Education (FLSHASE) faculty with two impactful inequality researchers. In addition, LIST was able to gain four PEARL fellows in its Materials Research and Technology department. Their positioning as leaders, however, is difficult to identify on the LIST website. The recruitment of a strong female PEARL fellows to direct space research at LIST has been described in the interviews as an important development. In ICT, two of the three UL SnT recruits have left Luxembourg, as well as one of the two PEARL fellows at LIST in this research field. PEARL fellows and other interview partners stated that visible, interesting research topics serve(d) as one of the main features attracting senior researchers to Luxembourg through PEARL.

Apart from the structural impact on the research landscape through the number of PEARL (and ATTRACT) recruits, some of the fellows have made an impact on the system through their research work with national and international partners. These effects can be seen in the fields of space research, in neurosciences (pathology, Parkinson's disease, Alzheimer's disease), or in the development of large transnational initiatives for patient data exchange in precision medicine. The establishment of strong PEARL research groups has made the Luxembourg system more attractive. As one interview partner stated: PEARL has contributed to a strong competition-oriented mindset. This has helped Luxembourg's researchers to become credible partners in large international consortia in several key areas, despite the *de facto* absence of internal competition in Luxembourg.

The PEARL program has also served to promote high-level interdisciplinary research and cross-sectoral cooperation. The FNR's National Centres of Excellence in Research (NCER) program provides a framework and a funding instrument to bundle research excellence around significant societal relevance. Three NCER projects serve as examples of how activities from PEARL funding complement other FNR funding initiatives.

- The *National Centre of Excellence in Financial Technologies* (NCER-FT) was launched in 2023 and is led by the PayPal-FNR PEARL Chair. Combining expertise from the SnT and the Faculty of Law, Economics and Finance (FDEF) at UL, the center focuses on supporting Luxembourg's position as an innovative financial hub through excellent research.
- CLINNOVA is the *Centre of Excellence in Digital Health and Personalised Medicine*. Founded in 2017, the center is the result of a fruitful collaboration between LIH, LCSB and UL in partnership with the Centre Hospitalier Luxembourg (CHL) and the Robert Schuman Hospitals. The aim is to collaborate with international research centers. In April 2023, a new Europe-wide precision medicine initiative was launched, supported by the FNR, the Grand Est, the Canton of Basel-Stadt and Baden-Württemberg. Within this initiative, the Luxembourg Centre for Systems Biomedicine is representing the University of Luxembourg. A former PEARL fellow will be the scientific principal investigator for the multiple sclerosis cohort study and three former ATTRACT fellows will also provide contributions to CLINNOVA.
- NCER-PD, the *National Centre of Excellence in Research on Parkinson's Disease*, is a decentralized research center that brings together key institutes in biomedical research in Luxembourg: the LCSB at LU, the LIH, and CHL, in collaboration with LNS. The NCER-PD is coordinated by a

former PEARL fellow and supported by two former ATTRACT fellows. The center aims to better understand Parkinson's disease to improve its diagnosis and treatment, focusing on participants in Luxembourg and its Greater Region. The Luxembourg partners also collaborate closely with other national and international clinics and research centers. Attached to the center is the *ParkinsonNet* initiative, which brings together various healthcare professionals and facilitates Parkinson's-specific specialization, interdisciplinary collaboration, and knowledge exchange amongst professionals.

Therefore, one major structural effect the PEARL program has already achieved is the recruitment of top researchers through the program, and the filling of very senior positions, either directly through the granting of a PEARL fellowship or through subsequent career steps. However, several interview partners now believe that this original mission has been accomplished, with some even now seeing an imbalance between senior and junior researchers in Luxembourg.

The Panel still sees a need *and* a valid intervention logic for PEARL, but not as a top-down activity. Due to governmental priority setting and FNR policy, PEARL has somewhat shifted its focus more towards strategic fit, with research excellence no longer being the primary overarching goal. This is further evidenced by the bibliometric study that indicated a somewhat lower performance of the funded PEARL fellows compared to those applicants not funded. Paradoxically, the program may have become more strategic as and because the system matured. More external / strategic direction was given to the program from 2016 / 2019 onwards, at a time when perhaps it was less needed. As PEARL fellows are major and influential placements, the stakes are correspondingly high for the various actors, who often have differing interests. The government wants a clear strategy and the FNR is directed more towards “mission-orientation”, while UL and individual LIs desire more leeway and see the FNR as a funding agency rather than as a policy actor. For a program like PEARL, context makes a difference. If thematic strategies for PEARL placements are enforced alongside the other thematic and mission-oriented funding programs, then the RPO leaders will see the PEARL program as part of a top-down policy that directs their strategies from outside. Such a perception is detrimental for a program like PEARL, where one of the most interesting features is the combination of a focus on strict excellence with the strategic development of the organization itself, i.e., guiding from within and not from outside.

Selection and Administrative Procedures

PEARL has been subject to many changes over time. The FNR, as stated also in the SAR, appears to harbor uncertainties as to how best to continue delivering the program. Due to these changes and uncertainty, it is difficult to assess the selection procedures in a general way. While several interviewees praised the quality of the FNR application and selection procedures, three features raised critical remarks. One issue is the lengthy procedures, specifically with Open PEARL (see below). The second point is the wish to also allow Luxembourg-based researchers to apply for PEARL, which is endorsed by the Panel. In another case, the FNR was criticized as being too strategic in the run-up to a PEARL call. The Panel cannot independently verify these claims. Overall, the interviewed PEARL fellows describe the entire selection phase as fair, professional, and high-level, with the exception of lengthy Open PEARL procedures and increasingly unclear program goals over time.

The Panel welcomes the idea that Luxembourg-based researchers can apply for PEARL grants, as PEARL is a top excellence program to allow the very best senior researchers to accomplish exceptional goals. Therefore, it should be open to scientists from abroad *and* from Luxembourg, given there is a level-playing field in the selection process and criteria.

Only two of the 17 PEARLs were awarded to women. This fact, already criticized in the 2017 evaluation, is a disappointing figure, particularly given the greater leeway the PEARL search process provides, compared to ATTRACT. Therefore, the FNR cannot be complacent and should actively pursue various avenues, ranging from advertising to deliberations and negotiations with RPOs that lead to effective signals and / or criteria.

The FNR should also be clearer and more demanding towards the RPOs in contractual matters. For example, greater detail regarding compliance should be provided in clauses such as: “The grant is a 5-year funding agreement between the FNR and the host institutions, with a 10-year expected timeline for the research programme” (SAR, p. 40). In such a setting, a funding agency has not much power to check whether RPOs fulfil their initial commitments after the actual funding period, indeed, at least one case of non-delivery has been reported to the Panel. A long-term, high-level, mutually binding trilateral contract between FNR – RPO – PEARL fellow should be considered as a remedy for different issues, synchronizing outcomes between RPO and FNR board decisions, long term promises that tend to be forgotten, misconception of a funding agency imposing on an RPO through large volumes of money, etc.

Like ATTRACT, the PEARL grant has lost part of its real value through inflation. In addition, it was also reduced in size a few years ago. Therefore, a few budget lines originally paid by the grant now must be mobilized by the RPO itself. These factors—plus the lack of overhead compensations—are detrimental to the vision of jointly financing the recruitment and establishment of world class leading scientists in Luxembourg.

As for ATTRACT, the international advertisement of the program was criticized in the interviews as being too limited. Related to this matter, some PEARL fellows reported that they expected / would have greatly appreciated more upfront information about specificities in Luxembourg, including labor law or other regulations when they were candidates.

As for ATTRACT, an external evaluation was also carried out for PEARL in 2017, the results of which can be found in the SAR from page 46 onwards. The following issues in particular were highlighted as isolated weaknesses: long time of the PEARL lifecycle process from pre-proposal to final decision; missing extensive monitoring of third-party funding of PEARL fellows; long-term planning as proven to be difficult due to changes in leadership and thus strategies and priorities in the different institutions; weaknesses regarding equity, diversity and inclusion in PEARL.

Specific issues: OPEN Pearl and Role of the Scientific Advisory Board

The overall PEARL program has been subject to experimentation and changes over the years (SAR, p. 46f.), including in the form of the OPEN Pearl that was first introduced in 2016. In the OPEN Pearl variant, the search for candidates starts once an important strategic niche has been identified. Three such awards (with a fourth in the process) have been awarded so far, i.e., about half of all PEARL fellows since 2016. Compared to the traditional PEARL, it introduced another step in the selection process and thus further extends the timeline (SAR, p. 41). The length of the process was subject to criticism in the interviews with durations up to three years (SAR, p. 49), some interviewees, however, appreciated the scheme. OPEN Pearl also risks being too narrow and thus may exclude excellent candidates from application: PEARL as such must take place within the national research priorities, and second, within that a strategic niche must be identified. The idea of an Open PEARL makes more sense through the strategic lens of an RPO than through that of a whole country: Which area does the RPO leadership want to expand? Where, therefore, to invest considerable sums and how to recruit a true research leader for

an important field? How to co-fund it with external actors like the FNR as it might be too expensive for the organization without third-party funding? Such questions might inspire the redesign of the PEARL program. Therefore, the current Open PEARL can be a good starting point for the discussion about a restructured PEARL.

Various interviewees endorsed the important role of the Scientific Advisory Boards for the individual PEARLs and advocated for such a role also in the future.

9. Reflections and Recommendations

General reflections for future development

Throughout the evaluation process, the Panel was impressed by the achievements of all involved Luxembourg institutions in setting up a highly functional and effective public research system yielding considerable outputs and impacts over the last two decades. ATTRACT and PEARL have played an important role as key FNR funding programs to gain top researchers for Luxembourg and to successfully integrate them into the RPOs. Across the programs, disciplines and organizations, both ATTRACT and PEARL are successful interventions, namely when it comes to scientific output and impact, and to the establishment of critical mass in important research fields, e.g., new materials, neurodegenerative diseases, digital solutions in various fields like telecommunications, security, health or the humanities. Although some cases posed challenges in aligning with evolving traditions at the host institutions, the two programs have provided important stimuli and incentives, namely for UL, LIST and LIH, to attract talent, to further develop career policies and to help create centers of excellence and critical mass.

Over time, the context for the two programs has changed due to the growth and maturing of the system. Compared to ten or fifteen years ago, each new top talent coming to the Luxembourg research system today enters an organization and environment that have a more developed culture, a larger existing pool of top people and a more defined profile. Therefore, each new generation of ATTRACT and PEARL fellows appear to bring a little less structural change to Luxembourg, and their future prioritization in the FNR funding portfolio is seen differently by various stakeholders.

This specifically holds true for the large PEARLs, with senior leadership positions linked to the fellowship, and the question of who de facto decides about such senior recruitments. Both variants—traditional PEARL and Open PEARL—are accompanied by tensions between the FNR and the future host institutions regarding the issues of how the candidates for key positions (and in the case of UL, full professorships) are selected, and by whom. Open PEARL somehow mitigates this tension but at the price of imposing very lengthy procedures. Therefore, different ideas have been expressed on how to deal with PEARL in the future, including by the FNR in their own SAR.

Recommendations

The Panel sees both programs as still highly relevant for Luxembourg. The reasons are twofold. Firstly, the structuring and establishment of the domestic public research system is advanced but is not complete. In international comparison, the system is in its infancy and even much older national systems still support comparable programs because factors like retirements, restructuring and new scientific and technological developments remain challenges. Second, Luxembourg is a distinctly small research system with the constant need to look for talent around the world. In that context, the two programs address important current and future needs for the country. This means that the Luxembourg R&D

system will continue to profit from these programs in the future, namely through the attraction of excellent people, the strengthening of important areas and through increased international visibility in science and technology.

Recommendation 1: *Keep both ATTRACT and a modified PEARL in the FNR funding portfolio.*

ATTRACT and especially PEARL currently must follow numerous goals, all under the banner of “excellence”. As stated in interviews and in the SAR, the FNR in the programs applies six dimensions of research excellence, including scientific impact, public outreach, teaching, societal impact, economic impact, and structural as well as systemic effects. This broad array of seemingly equally important goals appears to put a burden on researchers, institutions, and the programs themselves. The interviewees have reported cases of goal overload, while there is no indication in the SAR and the interviews for stringent monitoring and measurement for some of the criteria applied by the FNR.

As stated above, the main value of the two programs lies in the constant supply of top scientists from abroad for the Luxembourg research system, in addition to the recruitments the RPOs fund with their basic budgets. Therefore, scientific quality (and the FNR serving scientific research) should be the top priority of ATTRACT and PEARL. As successful areas like clinical data-driven research or space research show, these do not necessarily have to always be blue sky scientific endeavors. While other goals and criteria are also important, they should follow as secondary targets.

Recommendation 2: *The FNR should put the focus of both programs on scientific excellence and impact as the top funding criterion and research goal and treat other important topics as second-tier goals and criteria.*

This focus on research excellence should be safeguarded by continual efforts to maintain peer review and juries at the highest international level. In addition, the FNR should establish a better data basis in the monitoring of the projects. This could include not only outputs such as publications / patents, but also outcomes like further third-party successes in particular at the EU level and money from industry cooperation, career steps, or supervision of PhDs. It is also recommended to establish a publicly accessible and searchable project database on FNR’s website to increase visibility. To support the main goal of attracting top talent, the FNR should require that host institutions actively advertise the positions, especially ATTRACT, in international journals and other relevant channels more actively to increase the visibility of the program. That might also help prevent the practice of researchers already hired by the RPOs applying for the ATTRACT program. To support this main goal, it may also be necessary to increase advertising aimed at positioning Luxembourg as a location of internationally excellent research.

With both programs, the Panel has been informed about increased levels of bureaucracy and new rules over time. The FNR (and also the host institutions) should be aware of these issues. As ATTRACT and PEARL aim at recruiting and retaining top-class scientists, a high degree of freedom and flexibility should be safeguarded.

Recommendation 3: *The FNR should be aware that increased administrative control does not, in general, increase the performance of their fellows and that new administrative measures should only be implemented if absolutely necessary. It should also take care that administrative processes during the funding period are highly consistent over time and fellows but, at the same time, display enough flexibility to be able to respond to the individual needs of fellows. More effort should be directed towards*

the announcement of open ATTRACT and PEARL positions and on international marketing of the location.

ATTRACT has proven to be a strong and well-designed funding program, literally *attracting* top young and mid-career talent and effectively helping to incorporate the fellows into the organizations. The main structural (quality of candidates, careers, critical mass) and performance (publication and other impacts) goals have been achieved. Furthermore, the running of the program and providing of services by the FNR meet, in general, a very high standard. Therefore, the program can and should be continued in the current form. The necessary minor adaptations are in part due to external factors. For example, the high inflation rate in the last years has effectively diminished the value of the grant. The Panel argues for well-funded ATTRACT fellowships.

Recommendation 4: *Keep ATTRACT in its current shape as an incoming program. For the individual grants, it is advised to increase their financial volume due to two reasons: firstly, to re-establish the original real value of the ATTRACT funding; secondly, to allow the possibility of payment of overheads to the host institutions.*

ATTRACT might need an additional operational adaptation beyond lowering administrative burdens. With this program (and in contrast to PEARL), the main challenge comes at the end of the funding period with the loss of the guaranteed group budget. As ATTRACT is a kind of starting package comparable to those in other countries, many fellows must basically substitute it through further third-party funding. That can be challenging in Luxembourg, as the FNR is the only source in the country, and their CORE program comes with financial and procedural limitations. Therefore, it would be advisable to couple promotions at the end of the funding period with a certain minimum endowment. This might be negotiated between the FNR and the host institutions (potentially including MESR) as part of a greater deal: introduction of overheads, more strictness regarding tenure as practically all candidates receive tenure, and some longer-term resources for those successfully tenured. Potential issues with other FNR funding programs like CORE are recognized but beyond the remit of the Panel.

Recommendation 5: *The FNR and the host institutions should look for ways how the latter might support highly successful ATTRACT fellows through a minimum basic endowment after the end of the funding period.*

PEARL, in contrast, needs more substantial restructuring in order to fully realize the program's potential for providing top-class scientific research of global significance. In the view of the Panel, Luxembourg as a small, aspiring research location should retain a program with very large grants for top-class senior researchers in the future. Such a fellowship contributes to the international standing of the research location, as great researchers find generous working conditions. It also contributes to further consolidating and extending the strategic profile of the host institutions.

Several PEARL program features have proven their value: coupling with a senior / ultimate career step; long-term commitments by those who guarantee the funding; and rare use of the instrument. However, the nature of PEARL fellowships as beacons of scientific excellence should allow both researchers from abroad and Luxembourg-based researchers to become PEARL fellows, as long as the highest level of excellence meets a strategic perspective for the (future) host institution. As a strategic placement, PEARL should be used only rarely, however, for this reason be well rewarded including a career

advancement step and therefore consider a proper role of the applying organizations in the selection of the candidate. In contrast to ATTRACT, the main PEARL-related issues today occur at the opening stage. The selection process needs a design overhaul, based on several features: scientific excellence; fit to strategy of the RPO (see Recommendation 7); senior (of UL: academic) career step; a level-playing field between Luxembourg-based and candidates from abroad; finally, an adapted long-term perspective (see Recommendation 7). The process should be clear, simple, based on independent decision-making and less lengthy following the highest international standards. The career steps should allow for a strong organizational role but do not necessarily have to be top-management positions as the opening of these positions has become increasingly rare and the timing for finding these positions do not necessarily match with the selection cycle of PEARL. To provide clarity, PEARL should also not have different sub-lines of the program.

Recommendation 6: The FNR should further develop PEARL—largely based on the Open PEARL model—as a well-endowed, clearly shaped funding line for rare strategic placements of top-caliber scientific researchers and their teams. The Panel recommends that PEARL should be open for foreign and Luxembourg-based candidates and coupled with a senior career step. It should follow a clear and faster selection process in accordance with the highest international levels of quality assurance based on scientific merit and potential as key criterion.

PEARL fellowships should be used as rare, strategic, expensive placements of the highest scientific level as a long-term contractual arrangement between FNR, the host institution and the fellow. While the ten-year perspective is seen as appropriate by the Panel, the complete termination of FNR funding and contract after five years can lead to difficult conditions in the FNR – (rector / CEO of) host institution – fellow triangle. In many countries, such arrangements are stabilized by long-term contracts that bind the host institutions over the whole period but also give them some incentives through funding over the lifespan. Such a strong, binding long-term contract can support the basic idea of an adapted PEARL program: give generous funding for top placements at a level where RPOs alone cannot afford to establish a top candidate and his/her expensive field. Therefore, such a step can be seen as a joint endeavor. The FNR and the host institution each invest a large amount to make something special happen: The FNR through a larger funding sum than currently granted, again to make up for large inflation losses in the past years and to pay overheads, and the host institution to establish a strong group / field it wants to establish anyhow but cannot afford alone. In such an arrangement, the cost could be seen more as the realization of an extraordinary opportunity than a burden. The imminent generation change in the Luxembourg research landscape will make such endeavors possible and necessary. The next PEARL fellowships should avoid over-complicated multi-affiliations of fellows. The PEARL SABs have proven useful.

Recommendation 7: *The FNR should increase the maximum financial volume for a PEARL fellowship to equalize inflation losses and to provide some overheads to the host institution. FNR and the RPOs shall negotiate an open and transparent long-term, tripartite, and mutually binding model contract. Such a contract shall also allow for one clear (main) affiliation per PEARL fellow. The SABs should be continued.*

The share of female PEARLs and ATTRACTs is quite low, in spite of the FNR efforts and favorable national framework conditions for female careers. That fact has been criticized already in an external evaluation in 2017. Although this is mainly due to the low number of candidates proposed by the RPOs, action should be taken.

Recommendation 8: *FNR and the RPOs should further develop incentives and criteria to help increase the number of female candidates. In addition, efforts should be taken to support highly qualified partners of new recruits from abroad.*

Priority setting in Luxembourg follows the research priorities and the national research and innovation strategy and allows for planning and building of critical mass in a small country with a young R&D system. The FNR translates national priorities into selection criteria and procedures for many of their programs. With ATTRACT and PEARL, a strategic merit assessment (SMA) has been established to check whether pre-proposals fall under priorities or not. That mechanism draws criticism for not being sufficiently transparent nor broad. It also cannot always guarantee priority setting within the RPOs. In addition, several actors in Luxembourg have argued for a broader dialogue to better align the major FNR funding instruments and calls to the national priority setting.

Recommendation 9: *The FNR should develop a more transparent and broader SMA mechanism that takes institutional strategic fit stronger into account without compromising the focus on scientific excellence. In addition, the relevant stakeholders should organize townhall-style meetings to discuss priorities to be operationalized and the instruments to implement them.*

The fellows of the two programs strongly increase both the top leadership pool and potential for Luxembourg, as recent examples have impressively shown. In addition, the network of the fellows has strong potential for crosstalk, synergies, learning and future joint projects. The FNR, in pre-pandemic periods, has supported networking. There is some potential for action now.

Recommendation 10: *FNR shall re-establish and increase networking among ATTRACT and PEARL fellows and build up / enlarge instruments to increase the leadership potential of the former. These activities should be open to selected guests from outside (incl. industry) to increase the potential for knowledge transfer, cooperation and sponsoring.*

10. Acknowledgements

The Panel thanks more than 60 interview partners who provided valuable, open and sharing insights into the Luxembourg research systems and allowed the Panel to provide its recommendations. The Panel also thanks MESR for the support in particular for hosting the site visit during the stay of the Panel in Luxembourg and the FNR for the informative SAR.

11. Annexes

List of abbreviations

ADR	Autorisation à diriger des recherches, authorization to supervise research
C ² DH	Luxembourg Centre for Contemporary and Digital History at UL
CHL	Centre Hospitalier de Luxembourg
EMBO	European Molecular Biology Organization
ERC	European Research Council
FLSHASE	Faculty of Language and Literature, Humanities, Arts and Education
FNR	Fonds National de la Recherche / Luxembourg National Research Fund
ICT	Information and communication technologies
LCSB	Luxembourg Centre for Systems Biomedicine at UL
LIH	Luxembourg Institute of Health
LISER	Luxembourg Institute of Socio-Economic Research
LIST	Luxembourg Institute of Science and Technology
LNS	Laboratoire National de Santé
MESR	Ministère de la Recherche et de l'Enseignement supérieur
MSCA	Marie-Skłodowska-Curie Actions
NCER	National Centres of Excellence in Research
NRIS	Luxembourg's National Research and Innovation Strategy
RPO	Research performing organizations (= UL + LIST, LIH and LISER)
SAB	Scientific Advisory Board
SAR	Self-assessment report
SMA	Strategic Merit Assessment
SnT	Interdisciplinary Centre for Security, Reliability and Trust at UL
UL	University of Luxembourg

Extended evaluation questions from the Terms of Reference

Program implementation

- Are the program's goals and procedures (deadlines, selection criteria, selection procedures etc.) clearly communicated?
- Are the selection procedures conducive to achieve the program goals? (evaluation process, academic level of peers, time to contract, etc.)
- Are the roles and the responsibilities of the [FNR] program office transparent and appropriate?
- For Open PEARL: Is the recruitment process fit to purpose?
- Are the administrative procedures during the lifetime of ATTRACT and PEARL grants clearly defined and are they implemented in a way to support the success of the grantee?
- What is the role of Scientific Advisory Board (PEARL only)?

Performance (Outputs and Outcomes)

- What is the performance and quality of outputs of the ATTRACT and PEARL awardees in terms of scientific output, teaching, ability to attract 3rd party financing, etc.? Especially in comparison with similar positions (without PEARL / ATTRACT).
- How successful have the grantees been in the creation of new research groups that will not collapse on their departure?
- How well are the grantees integrated in the host institution in particular and the national research landscape in general?
- Were the ATTRACT and PEARL grantees successful to pursue their career in Luxembourg or elsewhere?

Performance (Impacts)

- What are the structural effects of both programs on the national research landscape?
- What are the positive and negative spillover effects of both programs?
- What has been the additionality of both programs?

Recommendation for the future development

- Is the current set-up and rationale of both programs still fit for purpose in the current research environment?
- What should be changed/adapted/improved?

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