ESFRI

European Strategy Forum
on Research Infrastructures

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Energy and Supply Challenges of Research Infrastructures

Report 2022/2023

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EXECUTIVE SUMMARY WITH RECOMMENDATIONS

In conjunction with the COVID-19 pandemic aftermath, Russian aggression on Ukraine has wide-ranging consequences for the EU, including high inflation, an immense energy cost increase, and a shortage of critical resources. All of these have pronounced effects on the sustainability and operations of research infrastructures (RIs), several of which face difficulties in providing continuous service. To address these topics, ESFRI has established a dedicated drafting group to look into the energy and supply challenges, also responding to a call by Council[1] to do so.

This report highlights the significant impact of the Russian aggression on Ukraine on the sustainability and operations of research infrastructures (RIs) in the EU. The energy crisis resulting from the Russian aggression poses a severe challenge to the RIs, predominantly analytical RIs[2], with energy-intensive RIs such as synchrotrons, computing centres, accelerator-driven particle sources, neutron facilities, research reactors, and lasers being the most affected. The shortage of critical resources and materials, such as some gases, rare isotopes, and permanent magnets, also presents a significant challenge to RIs, although they may not be a consequence of the war. The report presents recommendations to ESFRI, MS, and the EC based on good practices from ESFRI member countries and the discussion within the drafting group to address these challenges and enhance the future resilience of RIs. The recommendations include allocating additional funds and energy price capping for the most energy-intensive RIs, developing response plans that include actions aimed at greening the operations of RIs, considering the needs of the RI communities in the activities linked to the Critical Raw Materials Regulation[3], and setting up specific measures to support the Ukrainian research community. The report emphasizes the importance of preparing for future crises, increasing the resilience and preparedness of European society to cope with any present and future crisis.

A brief overview of the responses of the RIs

Results show the severity with which the RIs are impacted by the energy crisis, with almost two-thirds of the responding RIs significantly challenged by it. Among these, the most relevant issue faced by the RIs is the lack of finance due to the increased energy cost, flagged by 80% of the respondents. RIs emphasized that even a relatively small percentage increase in energy bills can have a very significant impact on the extent to which a RI can continue to operate. RIs commonly have a very high overhead, often of the order of 80% of the total budget, which in the short term has to be met regardless of whether the facility is operational (e.g. salaries of permanent staff). Finding savings out of the remaining operational margin - often of the order of 20% - has a very high impact on the number of days the RI can run. Synchrotron RIs are particularly strongly affected, with 5 out of 10 reporting a

[1] Council Conclusions on Research Infrastructures (2. 12. 2022), §13: *"[…] CALLS on Member States and the Commission through ESFRI, as well as RIs, to elaborate on scenarios to manage possible upcoming crises, including energy supply difficulties."*

[2] 149 RIs responded to the questionnaire. When asked about access to which resources the RI mainly provide, the majority responded with scientific equipment or sets of instruments: (86,6%), followed knowledge-related facilities such as collections (18,1%), archives and scientific data: 29,5%, and computing systems: 7,4%. Among 'Other' (8,7%), there were services such as expert advice, data analytics and training, but also robotic vehicles and platforms, sea-going vessels, and a wind tunnel.

[3] Proposal for a Regulation establishing a framework for ensuring a secure and sustainable supply of critical raw materials, COM(2023) 160 final.

planned interruption of operations. Among the other facilities foreseeing interruption of services were some other accelerator-driven particle sources, neutron facilities, a research reactor, a laser facility and a computing centre.

In addition to the energy challenges, the current crisis also leads to shortages of some key materials and products. In fact, 39% of the respondents stated that they experience problems with the supply of materials/equipment/parts/etc, which is not only due to the Russian aggression against Ukraine. They have particularly singled out shortages of some gases, such as Helium and Helium-3, Nitrogen, Argon and Xenon. Also, for many years, the Russian Federation has been the only provider of rare isotopes such as ^{48}Ca and ^{57}Co, and some advanced research apparatus, like superconducting wigglers. Permanent magnets, used by facilities such as synchrotrons, MRI instruments, etc, present another serious challenge. Cobalt, and some rare earths are crucial components of permanent magnets, the use of which can strongly reduce the energy consumption of some facilities.[4] The supply of e.g. cobalt is heavily concentrated, with a few countries dominating the production and trade of the mineral, none of which is in Europe.

There is currently no replacement for high-quality diamonds for X-Ray optics from the Russian Federation. RIs are also impacted by bottlenecks in the supply of electronic components, although this is not due to the Russian invasion of Ukraine.

While most supplies formerly procured from Russia can by now be substituted by other providers (e.g. magnets), they often bear a higher price tag. The high energy cost has significantly raised the price of some materials (e.g. Aluminium), and has pushed up inflation with its strong effects on all products and services and the cost of personnel. While the issues related to inflation are not specific to research, or research infrastructures, they may have profound effects on the operations of some research infrastructures.

RIs also reported that the delivery times of several instruments and spare parts have at least doubled, often to about 6 months. However, even longer delivery times are observed for some critical equipment, such as industrial-grade PCs, vacuum equipment, power transformers etc., which significantly delays any instrumentation upgrade. This has a direct impact on the planned timeframe of construction and upgrades of the RIs, which often leads to increased costs, but also on the calls issued by the funders, which need to consider prolonged delivery times. The delays also affect the scientific outputs and other aspects of RIs' work, such as training, which should be taken into account by RI's stakeholders.

Recommendations

The experience with the two crises, COVID-19 and the current energy one, provide valuable information from which policymakers, as well as RIs, can learn. During the pandemic, the resilience and resourcefulness of the RIs helped with some public measures, prevented the collapse of the RIs

[4] PSI's design of the SLS upgrade has permanent magnets already integrated in the accelerator, and has been estimated that the upgraded SLS 2.0 will use only 2/3 of the power nowadays being used for SLS. Also, SOLEIL upgrade, using permanent magnets, has estimated an optimized consumption as low as half of the power used in the present accelerator.

system even during the most difficult times. However, the financial burden of the current crisis in the case of the most energy-intensive RIs endangers their uninterrupted services.

The Competitiveness Council considers the European RI ecosystem a key component for the post-crisis recovery with a great potential to strengthen the resilience and preparedness of European society in order to cope with any present and future crisis and has called on ESFRI, as well as RIs, to elaborate on scenarios to manage possible upcoming crises, including energy supply difficulties.[5]

Recommendations presented here are based on good practices introduced by some countries during the current energy crisis. They are complemented by the further considerations of the drafting group. The intention behind the recommendations is to offer inspiration and guidance, even in the event of future crises, and their implementation is intended to be voluntary.

To the National Policymakers

1. In crisis situations, countries respond with **public measures addressing various sectors of the economy** as well as the general population. Countries are advised to **consider including the public research sector as beneficiaries of measures supporting business continuity** during crises. Regarding national and pan-European RIs, it is also important to keep in mind that they are included as a part of the public sector, as contracting energy supply has proven difficult for pan-European RIs that fall outside the national contracting consortia.
2. It is important for each country to understand **which of the RIs might be most affected** by the crisis. Such an overview is a precondition for the development of targeted support measures. The current energy crisis has the strongest effect on energy-intensive RIs such as synchrotrons, computing centres, accelerator-driven particle sources, neutron facilities, research reactors, and lasers.
3. Several of the energy-intensive RIs are not able to cover the increased cost of energy from their operational budgets. **Allocation of additional funds and energy price capping**, if not already available through general measures (under 1.), would enable RIs with the highest energy consumption to continue delivering their services during the crisis.
4. While immediate support measures may relieve the effect of the crisis, it is considered a good practice to **ask the RIs to develop a response plan**. In addition to **short-term measures**, it should also include actions aimed at the **greening of research infrastructure operations**. The existence and quality of such plans may be a part of national funding allocations and monitoring. ESFRI, for example, has included a question related to greening in its monitoring of ESFRI landmarks.
5. The plans for the greening of the operations should go beyond reducing **energy consumption** and green energy production and address the **reduced need for materials, their reuse and recycling**.

[5] Research Infrastructures - Council conclusions (approved on 2 December 2022) 15429/22

6. Where possible, the plans **for the greening of the operations should be accompanied by dedicated funding**, such as investments in green energy sources and the upgrades of the RIs (e.g. replacements of electromagnets with permanent magnets).

7. Beyond the energy crisis, the questionnaire revealed significant challenges related to the supply of materials. The funders are invited to **consider the longer delivery periods** in their support measures. In addition, they should be mindful of this when using time-limited resources, such as the ones from the Recovery and Resilience Facility.

8. A particular challenge is the shortage of some materials, which may result in significantly increased costs and even stop research in particular domains. Some of these effects can be counteracted at a national level. However, some solutions should better be considered at a European level. The **countries and the EC are invited to consider putting in place measures to address current shortages of materials**, such as, for example, ^{48}Ca and ^{57}Co.

9. Current delays due to supply challenges have significantly increased the cost of instruments and materials, and high inflation may require a **revision of cost estimates and a baseline of RIs under construction or undergoing upgrades**. Countries may consider opening dialogues on the topic with such infrastructures.

10. **The delays also affect the scientific outputs and other aspects of RIs' work**, such as training, which should be taken into account by RI's stakeholders. This should be acknowledged and monitored.

11. Ukraine stands out as a special case which will need particular support from the countries and the EC as the ongoing aggression has devastating impacts on scientific production and research infrastructures. The countries, through their RIs and the EC through dedicated funding, are invited to **consider putting in place dedicated measures to help the Ukrainian** research community rebuild its activities.

To ESFRI[6]

12. ESFRI, composed of national representatives and the EC, and tasked with policy coordination, should be **responsive to future disruptions affecting the operation of RIs**. Following the example of COVID-19 and the current energy and supply challenges, it should take similar steps in the future, fostering exchanges and mutual learning among its members and recommending ways forward.

13. ESFRI should **continue to stimulate activities, which will increase the resilience of RIs**. A good example is the inclusion of the topic of the reduced environmental footprint of RIs in ESFRI's monitoring questionnaire of ESFRI landmarks. The environmental footprint of RIs, once in operation, should also be considered when selecting RIs for the future ESFRI Roadmap.

[6] ESFRI is composed of national delegates and the EC. This section contains recommended activities of the countries and the EC, through ESFRI, while recommendations to the EC alone are addressed in the following section.

14. Recently the EU became more aware of the extreme global dependency of certain industries on a very limited number of actors in a complex geopolitical context and had, as a result, decided to strengthen its technological leadership with e.g. European Chips Act and EuroHPC partnership. The current crisis reveals a similar dependency of the RIs on materials and supplies which are scarce or unavailable in Europe. **With the help of RIs, ESFRI should identify such key resources so that the solutions can be developed jointly by the MS or the EC and the continued operations of RIs secured**.

15. In its statement on Russian aggression towards Ukraine,[7] ESFRI called for Research Infrastructures and their funders, within their capabilities and legal framework, to aid the Ukrainian research community where possible. Until now, funders and the RIs have put in place a number of activities to support the Ukrainian research community. ESFRI is invited to **prepare a brief overview of activities to support the Ukrainian research community in order to enable the exchange of good practices and to highlight the ongoing efforts**.

To the EC

16. Beyond national investments, the European Commission has a particular role in facilitating the development of joint approaches and technologies across RIs, through framework programmes funding. Such support is considered of very high European added value. The EC is invited to **consider EU-level funding instruments to support investments in greening and sustainability of RIs**, following on a good example of the INFRATECH pilot in the current Work Programme.

17. This survey of RIs has identified some key raw materials strategically important for the functioning of certain RIs in the longer term. In this respect, the EC's recent proposal of a European Critical Raw Materials Act[8] is particularly welcomed. **The Countries and the EC are invited to consider the needs of the RI communities in their actions linked to the Act**.

18. EC is also addressed in paragraphs 8, 11, 14 and 22.

To the RIs

19. The resilience of the RIs has been demonstrated during the COVID-19 pandemic, when numerous RIs secured uninterrupted service delivery and thus contributed to the pace of crisis resolution. In order to be prepared for current and future crises, the RIs are invited to **prepare plans, which would maintain their operation under changed circumstances**.

20. The current energy crisis strongly affected particularly energy-intensive RIs. While the adoption of energy-saving plans, such as lower heating and air conditioning, has only a minor

[7] ESFRI statement on the Russian aggression towards Ukraine, 16.3.2022, https://www.esfri.eu/latest-esfri-news/esfri-statement-ukraine

[8] European Commission, Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, Brussels, 16.3.2023 COM(2023) 160 final.

effect on the energy consumption of these institutions, they should consider putting in place **mid-term plans to decrease their dependency on external energy provision**. These could involve investments in green energy sources, the use of less energy-intensive processes, etc.

21. Beyond the topic of energy, in anticipation of increased climate challenges, the plans should also consider general **greening of operations by decreasing the amount of waste, as well as increasing reuse and recycling** etc.

22. Particular attention should be paid to the **use of critical raw materials**, the shortage of which may interrupt RI operation. They should review the requirements for such materials and instruments and inform ESFRI and the EC so that solutions can be considered in advance. The forthcoming proposal for a Critical Raw Materials Regulation may be helpful in this endeavour.

23. Research in Ukraine has been severely disrupted due to Russian aggression, and several RIs were destroyed. RIs are invited to **set up specific measures in support of the Ukrainian research community**, such as access provision, training, provision of scientific equipment, etc.

REPORT ON THE QUESTIONNAIRE ADDRESSED TO THE RESEARCH INFRASTRUCTURES

Summary

The Russian aggression on Ukraine, in conjunction with the COVID-19 pandemic aftermath, has wide-ranging consequences for the EU, including high inflation, an immense energy cost increase, and a shortage of critical resources. All of these have pronounced effects on the sustainability and operations of Research Infrastructures (RIs), several of which face difficulties in providing continuous service. To collect information about the challenges, a survey was developed and sent by ESFRI to the RIs in late December 2022. This report analyses the responses of one hundred forty-nine (149) Research Infrastructures[9], which have responded by January 31st. One hundred sixteen (116) RIs have completed the survey in its entirety, which demonstrated the high relevance of the topic. Furthermore, upon the request from the RIs, a dedicated questionnaire was sent to nodes of distributed infrastructures Euro-Bioimaging and EU Solaris, where a further 19 and 5 responses, respectively, were collected. These responses have been included in the analysis, apart from where noted.

Results demonstrate the severity with which the RIs are impacted by the energy crisis, with almost two-thirds of the responding RIs significantly challenged by it. Other challenges were related to the supply of resources and instruments and their cost and increased delivery times, all interfering with the delivery of services, their development and planning. They are addressed in this summary one by one.

Energy Challenges

The majority (62% of 173 RIs) of respondents experience significant challenges related to the current energy crisis[10]. The most relevant issue faced by the RIs is the lack of finance due to the increased energy cost, flagged by 80% of the respondents (n=75)[11]. In addition, conformity with the requirements imposed by the governing body/governments/funders (11%) and insufficient energy supply (9%) were raised by the RIs.

The severity of the situation is not uniform across Europe nor RIs and also during the survey due to the fluctuating energy prices and the introduction of various measures by the countries, such as subsidies for energy bills and a price ceiling on gas. The extent of the impact on the RIs also depends on e.g. whether they have short or longer-term contracts with energy suppliers. Thus, the spread of replies to the question of the difference in the energy bill between November 2021 and November 2022 was very high. While it was 10% or below for 16% of respondents, the majority reported a significant increase in energy bills, even up to 400%. It has to be noted that these responses were primarily

[9] When asked access to which resources the RI mainly provide, the large majority listed Scientific equipment or sets of instruments: 86,6% (129 RI), followed by Knowledge-related facilities such as collections: 18,1% (27), Archives and scientific data: 29,5% (32), Computing systems: 7,4% (11) and Other: 8,7% (13). Among 'Other' there were services such as expert advice, data analytics and training, but also robotic vehicles and platforms, sea-going vessels, and a wind tunnel.
[10] For the two distributed RIs significant challenges were reported by 47,4% of responding Euro-Bioimaging nodes (19 responses in total) and 80% of the responding nodes of EU Solaris (5 responses in total).
[11] Indicates the number of received responses.

received from single-sited facilities, thirty-seven (37) in total, since the information was not available for the distributed ones.

Even a relatively small percentage increase in energy bills can have a very significant impact on the extent to which a RI can continue to operate. RIs commonly have a very high operational overhead, often of the order of 80% of the total budget, which in the short term has to be met regardless of whether the facility is operational (e.g. salaries of permanent staff). Finding savings out of the remaining operational margin - often of the order of 20% - therefore has a very high impact on the number of days the RI can run.

Due to the severity of the crisis, the RIs have put in place (25%), or are preparing plans (40%) on how to address it (n=138). Such plans were largely (74%) requested by the funders, government, owner or governing body of the RIs. Again, this question could not be properly addressed by the distributed RIs, since the national nodes follow the policies of the institutions which own them, while the framework is provided by the country where they are located.

Such plans largely involve relatively small measures such as decreased heating and air conditioning. However, the extent of the crisis is asking for extreme measures. In several cases of analytical facilities, energy consumption is, however, in major part related to the operation of research equipment or a facility, so its reduction is directly correlated to business discontinuity or disruptions. Around a quarter of the RIs (31 RIs) which have introduced or plan to introduce measures to respond to the energy challenges (n=123), plans to close down operations for a period of time. Apart from one computing centre, these facilities mainly provide access to scientific equipment or sets of instruments. Synchrotrons are particularly strongly affected, with 5 out of 8 who responded reporting a planned interruption of the operations. In addition, several (12 facilities aim to delay or reduce the scope of major projects or construction.

While the current energy crisis requires the setting up of emergency action plans and *ad hoc* activities to decrease energy consumption, the climate crisis requires systematic greening of the facilities, processes and activities as a long-term strategy of RIs. While decreasing energy consumption and using green energy sources is a part of the greening of operations, it also includes activities such as continuous development of eco-friendly processes, sustainable use of resources, and their reuse and recycling. Due to its importance, such a plan is also a part of the ongoing monitoring of landmark RIs by ESFRI. In this survey, a fifth of the RIs have reported that they have such a plan, while a further quarter are preparing it.

Supply of Resources and Instruments

The current crisis also leads to shortages of some key materials and products, although not all of the listed ones are linked to the Russian aggression on Ukraine, as also remarked by several respondents. 39% of the respondents (n=129) stated that they experience problems with the supply of materials/equipment/parts/data/etc. They have particularly singled out shortages of some gases, of which the Russian Federation or Ukraine are among the leading suppliers, such as helium and ^{3}He, nitrogen, argon and xenon. Also, for many years, the Russian Federation has been the only provider of rare isotopes such as ^{48}Ca and ^{57}Co, and some advanced research apparatus, like superconducting

wigglers. There is currently no replacement for high-quality diamonds for X-Ray optics from the Russian Federation. Furthermore, some critical materials may significantly affect the future operations and greening of certain RIs. Cobalt, and some rare earths are crucial components of permanent magnets, the use of which can strongly reduce the energy consumption of some facilities[12]. The supply of e.g. cobalt is heavily concentrated, with a few countries dominating the production and trade of the mineral, none of which are in Europe.

The bottlenecks also impact RIs in the supply of electronic components.

Increased Delivery Times

RIs report that delivery times of several instruments and spare parts have at least doubled, often to about 6 months. However, longer delivery times are observed for some critical equipment, such as industrial-grade PCs, vacuum equipment, power transformers etc., which makes any instrumentation upgrade extremely time-demanding. This has a direct impact on the planned timeframe of construction and upgrades of the RIs, which often leads also to increased costs, but also on the calls issued by the funders, which need to consider prolonged delivery times.

[12] PSI's design of the SLS upgrade has permanent magnets already integrated in the accelerator, and has been estimated that the upgraded SLS 2.0 will use only 2/3 of the power nowadays being used for SLS. Also, SOLEIL upgrade, using permanent magnets, has estimated an optimized consumption as low as half of the power used in the present accelerator.

Introduction

The Russian aggression on Ukraine has wide-ranging consequences for the EU, including high inflation, an immense energy cost increase, and a shortage of key resources. All these have pronounced effects on the sustainability and operations of Research Infrastructures, several of which face difficulties in providing continuous service.

Energy-intensive infrastructures, such as synchrotrons, may find themselves incapable of providing an additional few million EUR each for the electricity bills per year and may be forced into extended, unplanned shut-downs. Furthermore, some RIs also rely on Russia to provide materials or parts of the installations for their operation. An example of such impact concerns the Mossbauer spectroscopy community, where the only two companies producing the needed ^{57}Co isotope have stopped their delivery to Europe, endangering the operations of 190 laboratories and 1300 researchers within the European Economic Area.

European Research Infrastructures have demonstrated their resilience during the pandemic, during which several have supported researchers, at least for COVID-19-related research, uninterruptedly. This was only enabled by their dedication and commitment, which enabled them to introduce measures such as increased remote access in a short time. The extent of the current crisis is, unfortunately, well beyond what the RIs can resolve themselves.

ESFRI is a body composed of national representatives and the European Commission to support a coherent and strategy-led approach to policy-making on Research Infrastructures in Europe. It is, therefore, the appropriate setting to discuss the considerations and approaches at the national level to address the issues and help RIs them as much as possible to overcome the current crisis.

To this end, ESFRI held its first exchange on the topic on its meeting in Brno on November 18th, and decided to set up a group which is to prepare a report for ESFRI.

This activity is well aligned with the Competitiveness Council's Conclusions of 2nd December 2022, which called on Member States and the Commission through ESFRI, as well as RIs, to elaborate on scenarios to manage possible upcoming crises, including energy supply difficulties.

The current emergency links to a broader priority of green transition, which is also relevant for Research Infrastructures, and which may be covered by the group. The Competitiveness Council Conclusions of 2nd December 2022 stress that the long-term sustainability of RIs does not stop at financial or human resources considerations but that their environmental impact should also be taken into account, and calls on Member States and the Commission through ESFRI, as well as RIs, to reflect on this impact and to develop methods for measuring it. This was also echoed by the Brno Declaration on Fostering the Global Ecosystem of Research Infrastructures, which stressed that the environmental impact and the climate footprint of RIs must also be considered to strengthen their resilience and to contribute to the sustainability of R&I sector. The topic of greening or Research Infrastructures is very pertinent given political priorities and policy measures, such as e.g. EC's Cities' mission, with 100 cities aiming to achieve climate neutrality by 2030. Lund, where Max IV and ESS are located, is one of the 100 cities. At the same time, Geneva, the home of CERN, has declared a climate emergency and is acting through its Climate Strategy to become 100% renewable and reach carbon neutrality by 2050.

These policy approaches will impact the long-term operations and sustainability of RIs, which warrants its elaboration by ESFRI. To this end, ESFRI has established a drafting group to elaborate on the topic and prepare its discussion. In the frame of this work, a questionnaire was prepared and shared with the RI community in December 2022. In the following, the results of the questionnaire are presented.

Respondents to the Questionnaire

The questionnaire is included in **Annex 1**. It was prepared by the drafting group and submitted to the RIs on 12th December 2022, with one hundred forty-nine (149) responses received by 31st January 2023 and analysed in this report. One hundred sixteen (116) institutions have reached the end of the questionnaire. Over half of the respondents were national RIs open to international users[13], followed by ESFRI Landmarks, ESFRI Projects and national RIs.

An adapted questionnaire was sent to nodes of distributed infrastructures Euro-BioImaging and EU-SOLARIS, where further twenty-four (24) responses – nineteen (19) and five (5), respectively – were collected. Eighteen (18) of them filled out the survey in its entirety. These responses, both from the primary and the adapted questionnaires, are included in **Figure 1**. Responses from national nodes of Euro-BioImaging and EU-SOLARIS are categorized as "national RIs open to international users". Their responses are, where applicable, also included in the analysis below. The number of respondents is given in brackets when reporting on each question.

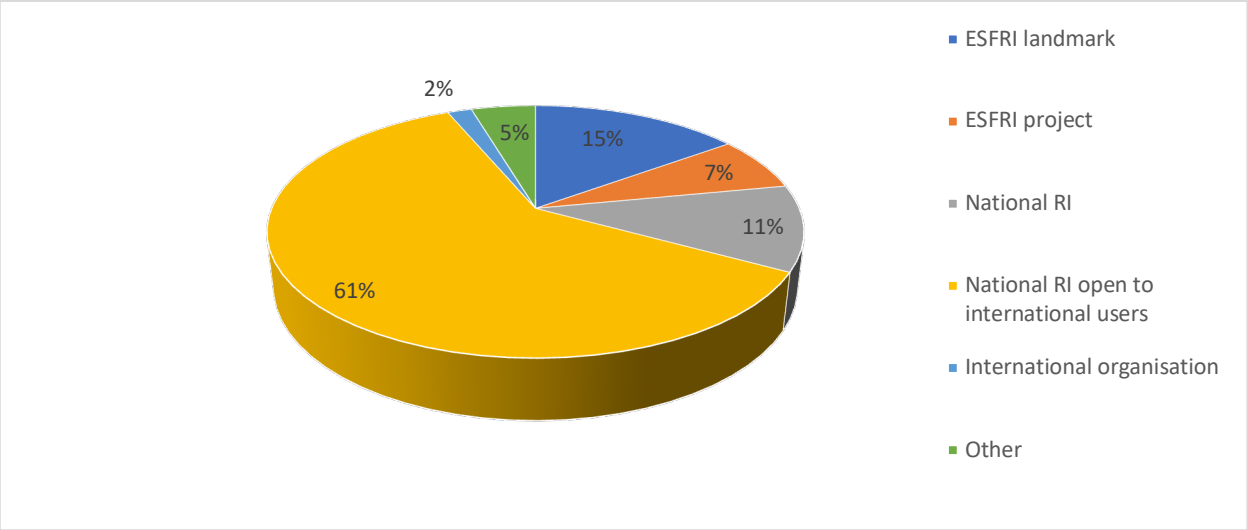

Figure 1: The type and the distribution of respondents.

Together with responses from Euro-BioImaging and EU-SOLARIS nodes, national RIs open to international users represent 61% of all responses. The group 'other' includes two networks of RIs, two national nodes of ESFRI Projects, and responses such as H2020 RI-project, TRI, non-ESFRI ERIC.

When asked access to which resources the RI mainly provide (multiple answers were possible), the vast majority of the responders (n=173) indicated 'Scientific equipment' or 'Sets of instruments' (88%), followed by 'Archives' and 'Scientific data' (27%), 'Computing systems' (21%), 'Knowledge-related

[13] National nodes of ESFRI Landmarks are included in this category.

facilities' such as collections (17%) and 'Communication networks' (7%). Among 'Other' (8%), there were services such as expert advice, data analytics and training, but also robotic vehicles and platforms, sea-going vessels, and a wind tunnel. Both single-sited (58%) and distributed RIs (42%) were well represented.

Results – Energy Challenges

The majority (62% of 173 RIs) of respondents experience significant challenges related to the current energy crisis. This is largely (80%) linked to the lack of finance due to the increased energy cost, but also due to the conformity with the requirements imposed by the governing body/governments/funders (11%) and insufficient energy supply (9%). A number of other energy-related challenges were identified, such as the impact on new process development, increased inflation partially due to the energy crises, and the difficulties in budgetary and operational planning due to the uncertain energy prices.

The severity of the situation is not uniform across Europe nor RIs and also fluctuated during the survey due to the fluctuating energy prices and the introduction of various measures by the countries, such as subsidies for energy bills and a price ceiling on Russian gas. The extent of the impact on the RIs also depends on e.g. whether they have short or longer-term contracts with energy suppliers.

Thus, the reported change in energy bill between November 2021 and November 2022 varied significantly among the 39 RIs who reported the data. Two RIs reported a minor increase of 10% in the energy bill, while one RI even reported a decrease. The majority of RIs (24, or 62%) however, reported an increase in energy bill between 20% and 100%, and some RIs reported larger increases, even up to or over 400% (**Figure 2**).

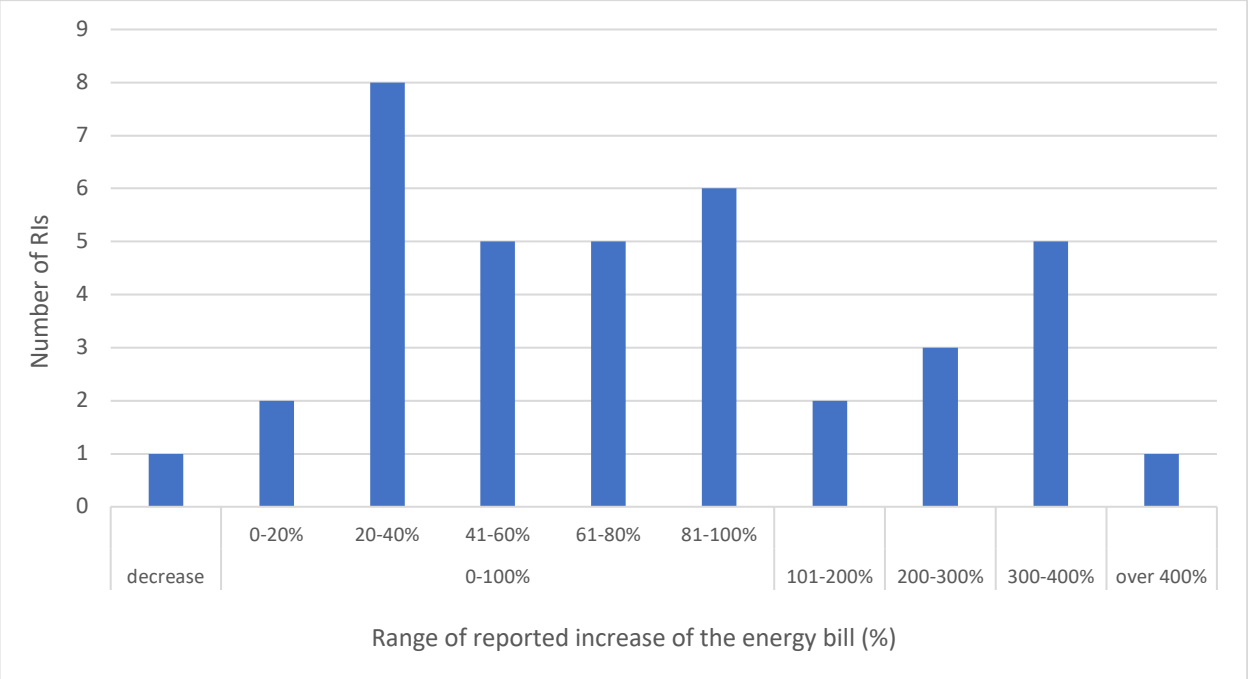

Figure 2. Frequency distribution table presenting increase in the energy bill for November 2022 compared to November 2021 (%). Thirty-nine (39) RI reported the data.

Implemented or Planned Measures

Among the RIs who introduced or planned to introduce measures to respond to the energy challenges (n=123, multiple answers possible), thirty-one (31, corresponding to 25%) reported closing down for a period of time (**Figure 3**). Apart from one computing centre, these facilities mainly provide access to scientific equipment or sets of instruments. Synchrotrons are particularly strongly affected, with five (5) out of eight (8) who responded reporting a planned interruption of the operations. In addition, several (17) facilities aim to delay or reduce the scope of major projects or construction.

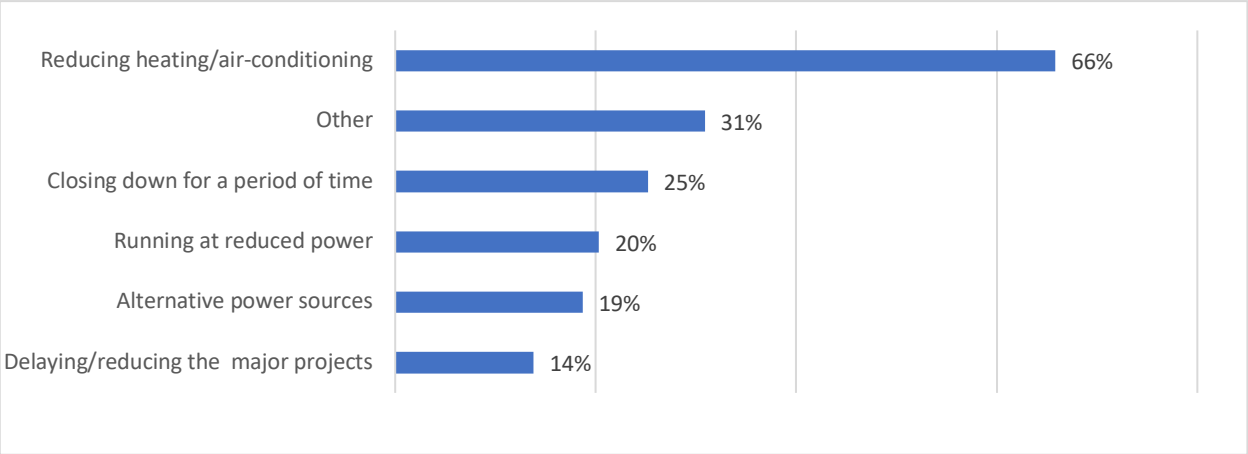

Figure 3. Measures introduced/planned to respond to the energy challenges (123 respondents who could select multiple answers)

Governance Responses Related to Crisis

Decreasing energy consumption

About a quarter (25%) of respondents (138) stated that they have a plan on how to address the current energy challenge, while a further 40% are preparing it. This question could not be properly addressed by the distributed RIs, since the national nodes follow the policies of the institutions which own them, while the framework is provided by the country where they are located. However, the figure includes the national nodes of distributed RIs which received their dedicated questionnaires.

The measures requested by the government that were most often mentioned were relatively smaller ones, such as decreased room temperature. In addition, some RIs report that such plans go beyond energy savings and may address, for example, contingency plans for energy shortages and failures, also to ensure sensitive equipment is not damaged should such an event happen. Furthermore, for some RIs in operation it was requested to report insights into enhanced costs, how it will affect the schedule and propose alternative scenarios.

Greening of operations

While the current energy crisis requires setting up emergency action plans and *ad hoc* activities to decrease energy consumption, the climate crisis needs systematic greening of the facilities, processes and activities as a long-term strategy of RIs. While decreasing energy consumption and using green energy sources is a part of the greening of operations, it also includes activities such as continuous development of eco-friendly processes, sustainable use of resources, their reuse and recycling.

When asked whether the RIs have a plan aimed at the greening of their operations, 25% (out of 136) responded that they have such a plan, while a further 35% are preparing it. Respondents who have a plan in place, were asked who has asked them to prepare such a plan. Contrary to the plans related to the current energy crisis (**Figure 4**), preparation of the plans to green the operations was largely own initiative of the RIs (77%; n=31), or of the institution which owns the RI (e.g. university), rather than RI's governing body, funder or a government.

RIs reported that the activities aimed at greening their operations are not new. In fact, the 6th workshop "Energy for Sustainable Science at Research Infrastructures (ESSRI) 2022", was jointly organised at the ESRF, over two days by CERN, DESY, ERF member laboratories, ESRF, ESS, PSI, and in cooperation with the IFAST programme. The event brought together international sustainability and energy experts, stakeholders and representatives from research facilities and future Research Infrastructure projects worldwide, with the purpose of identifying the challenges, best practices and policies to develop and implement sustainable solutions at Research Infrastructures. This includes the increase of energy efficiencies, energy system optimizations, storage and savings, implementation and management issues as well as the review of challenges represented by potential future technological solutions and the tools for collaboration.

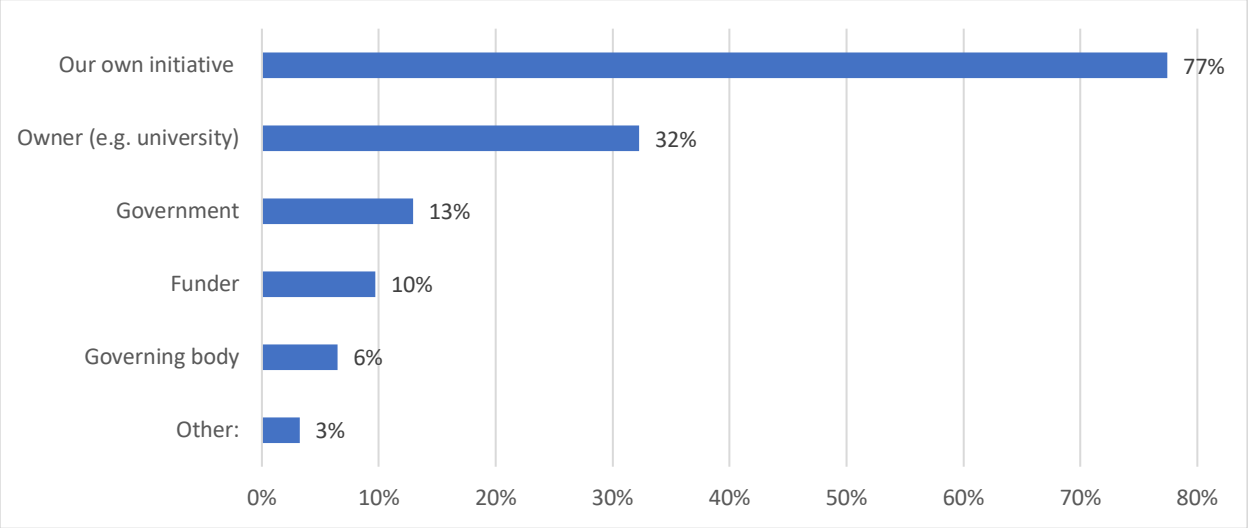

Figure 4. Who has asked you to prepare the plan for the greening of the operations?

Results – Supply and Other Challenges

In addition to the questions related to the current energy challenges, the institution experience also challenges related to the supply of materials and products, which are addressed in this chapter.

About 41% of the respondents (n=129) stated that they experience problems with the supply of materials /equipment/parts/data/etc, due to the Russian aggression against Ukraine (**Figure 5**). Some respondents stressed that the supply challenges reported may not all be due to the Russian aggression.

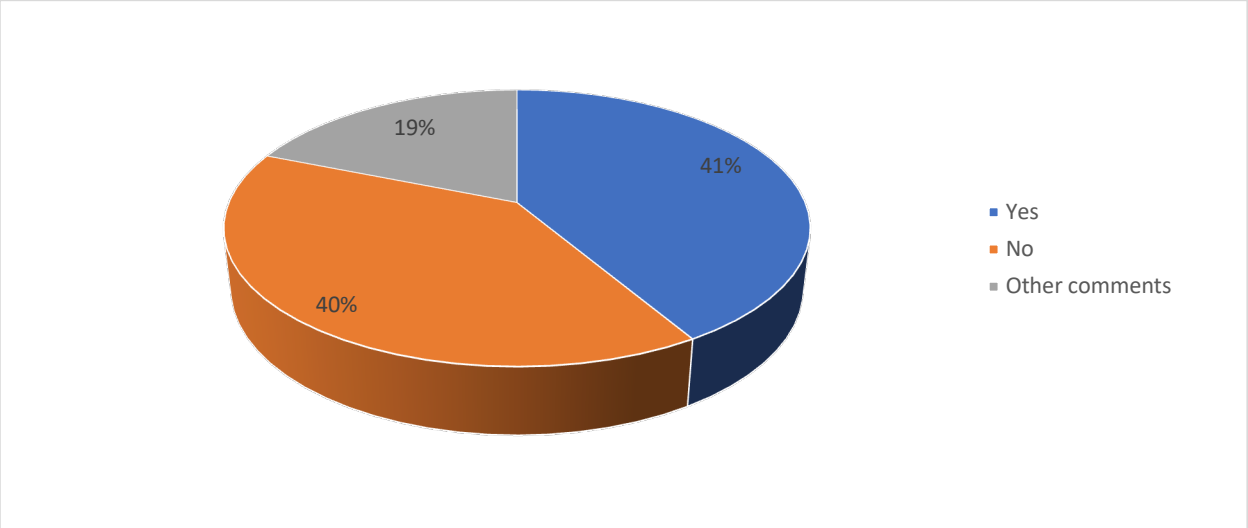

Figure 5. Do you face problems with the supply of materials equipment/parts/data/etc, due to the Russian aggression against Ukraine?

One respondent commented that most supplies formerly procured from Russia can by now be substituted by other providers (e.g. magnets), although in some cases for a higher price. Procurement of high-quality diamonds for X-Ray optics from Russia has not been possible to be replaced yet.

Among the 'other' challenges, respondents mentioned delays in deliveries and growing prices. The respondents questioned whether all of the supply challenges are related to the Ukraine-Russia conflict as they observe delays in the delivery of the general materials supply from e.g. China and face problems in purchasing the needed equipment. In fact, since the COVID crisis, supply chains have been unstable and unpredictable, leading to delays and inefficiencies. In addition, e.g. global supply bottlenecks lead to issues with purchases of electronic equipment.

When asked about the specific supply issues, the respondents listed mainly the following challenges.

Other Supply Challenges

The following challenges are not necessarily linked to the Russian aggression against Ukraine:

- Shortages of natural gas and shortages of some gasses such as helium (liquid, gaseous and 3He), nitrogen, argon, xenon.
- For many years, the Russian Federation has been the only provider of rare isotopes such as 48Ca. An initiative has been launched to solve this issue in the context of the NuPECC Long Range Plan.
- Isotope-labelled compounds.
- Budker Institute in Novosibirsk was the only supplier of some advanced research apparatus (like superconducting wigglers).
- Nuclear fuel for LVR-15 is manufactured in Russia.
- Shortage of some raw materials, reagents, alloys of some metals, semi-finished products.
- Medicinal chemistry synthesis in Ukraine was interrupted.
- Bottlenecks in the supply of electronic components:
  - Delay in the manufacturing of custom electronics due to missing parts/components.

- Significant delays of automation equipment due to the global semiconductor shortage situation as well as computing hardware, particularly high-performance computing. Similarly, there are delays eg. regarding special cables, specialised/customised connectors

Cost of Materials

- Much increased costs for raw materials, e.g. aluminium (which requires lots of energy in its production).
- Increase in the price of some technical gases or other materials.

Increased Delivery Times from Retailers

- RIs report that delivery times of several instruments and spare parts have at least doubled (to 6 months).
- Extremely long delivery times for critical equipment: industrial-grade PCs, vacuum equipment etc., which makes any instrumentation upgrade extremely time-demanding. I.e. vacuum valve or turbo molecular pump delivery time is 1 year.
- e.g. waiting time for new power transformer > 5 year.

Furthermore, some critical materials may significantly affect the future operations and greening of certain RIs. Cobalt, and some rare earths are crucial components of permanent magnets, the use of which can strongly reduce the energy consumption of some facilities. The supply of e.g. cobalt is heavily concentrated, with a few countries dominating the production and trade of the mineral, none of which are in Europe.

REPORT ON THE QUESTIONNAIRE ADDRESSED TO THE ESFRI MEMBERS

Seventeen (17) ESFRI members[14] responded to the dedicated questionnaire (**Annex 2**) between 13th February and 6th March 2023. The countries are generally concerned about the effects of the current crisis on the delivery of services by RIs. They mention the risks that interruption of the services may have on certain types of research, the potential decrease of highly expert manpower at the RIs, and the impact on research projects requiring the support of RIs. Also, the users may be discouraged from applying for the RIs services if the success rate decreases even more due to the reduced capacities of the RIs, or may turn to the RIs with uninterrupted operations. The respondents also highlight that in most cases, disruption of the services is more costly than the increased energy cost and that the disruption of their services provides almost no energy saving on global terms. As a result, several countries across Europe have, to varying degrees, responded to the energy crisis through a number of different measures. Firstly, several (8/17) have introduced **general measures to shield consumers** from the direct impact of rising prices, such as price caps and temporary tax breaks, vouchers and subsidies. Half of the responding countries have reported that the RIs are able to benefit from these measures, mainly referring to the energy price capping and tax breaks.

In addition to the general measures, a third of the responding ESFRI members (6/17) introduced **specific immediate measures to support uninterrupted science production**, including the continuous delivery of services by the RIs during the current crisis.

- CZ has provided an *ad hoc* extra-budgetary allocation to combat the energy prices skyrocketing before the energy prices capping by the Czech Government's resolution, which followed.
- SI introduced price regulation for energy supply (electricity, gas etc.) for public research-performing organisations (not specifically RIs) on the governmental level.
- DE provided special funding for federally (co-)funded RIs with high-intensive energy consumption. This funding provides an additional price cap for these institutions. Federal funds for this measure total 500 million Euros.
- FR has granted “energy subvention” to the research organizations at the end of 2022 in order to face the energy crisis in 2023. Some of the research infrastructures supported by the national research organisations could benefit from this subvention.
- LT has increased core funding in 2022 and 2023.

In addition to the specific support measures, five (5 out of 17) ESFRI members **asked the RIs to implement activities related to the energy crisis**, which involved the preparation of a plan of measures to address the energy and/or supply challenges (5) and reduction of energy consumption (4).

Beyond the current crisis, several countries (10/16) also consider **mid-term measures** that do not necessarily have an immediate impact on the current situation but will strengthen readiness for possible future shocks and aid the greening of RI operations. 6 (out of 17) ESFRI members asked RIs to prepare a **plan for the greening** of research infrastructure operations. Some countries consider such activities in their funding allocations. For example, FI has been asking the RIs to describe in the **funding**

[14] AT, CZ, DE, DK, ES, FI, FR, HR, HU, IT, LV, NO, PT, SI, SK, TK, UA

applications how well the research infrastructure and project take into account the necessary steps for the transition towards carbon neutrality in the construction and/or operation of the research infrastructure. The same topic is also addressed in **their national roadmap**. Some also have **specific financial support for the greening of the operations**. FR reports funding energy renovation projects, including in RIs, by the dedicated national recovery plan, while HU dedicated funding from the national budget to build solar panels on the site of ELI-ALPS with a 3 MW capacity to reduce energy consumption by 30%. Implementation started in 2022 and is expected to work at full capacity by 2026. AT reported that in the course of the flagship project Quantum Austria, financed by RRF (Recovery and Resilient Facility), the further increase of HPC capacity was strictly bound to greening measures in terms of energy consumption both for computing and for cooling. Such requirements will also be negotiated within the coming Performance Agreements with all universities and the RPOs (research performing organisations) that receive global budgets from their ministry.

Activities in Ukraine in times of Russian aggression differ from the other respondents, as they mainly focus on continuing professional activities in safe conditions. To protect them from Russian aggression, universities were moved to safer regions of Ukraine from the areas of hostilities. However, the research equipment was mostly not moved. The Ministry of Education and Science of Ukraine has collected the needs for technical equipment, which would allow the institutions to pass the winter period and has purchased autonomous generators for uninterrupted power supply during damage by Russian missile strikes to the energy system of Ukraine.

ANNEX 1

Energy and Supply Challenges – Questionnaire for RIs

Welcome to the ESFRI questionnaire on energy and supply challenges of research infrastructures.

Due to the current energy and supply challenges faced by the research infrastructures, ESFRI established a dedicated group which should provide its members (member states, EC and associated countries) with an overview of the situation and possible ways of addressing the challenges.

To be able to deliver on the task, we have designed a brief questionnaire for RIs. We kindly ask you to complete this survey by clicking on the Next page.

The questionnaire will take about 5 minutes, but you might need to obtain some data from other departments. The deadline for responding is January 6th 2023, end of day. If you require additional information or clarification of the questions, please feel free to write to us at esfri@fdv.uni-lj.si.

For viewing purposes only, please find the questionnaire in PDF.

Q1 - Name of Research Infrastructure (RI)

_____

Q2 - Type of research infrastructure

- ○ ESFRI or non-ESFRI ERIC
- ○ International organisation other than ERIC
- ○ National RI open to international users
- ○ National RIs
- ○ Association/network of RIs
- ○ Other:

Q3 - Access to which resources does the RI provide?

Multiple answers are possible

- ☐ Scientific equipment or sets of instruments
- ☐ Knowledge-related facilities such as collections
- ☐ Archives and scientific data
- ☐ Computing systems
- ☐ Communication networks
- ☐ Other:

Q4 - What kind of RI are you?

- ○ Single sited
- ○ Distributed

IF (1) Q4 = [1]

Q5 - Please name the country, where it is located

_____

Q6 - Do you experience significant challenges related to the current energy crisis?

○ yes

○ no

IF (2) Q4 = [2] and Q6 = [1]

Q7 - The questionnaire is not adapted for a distributed infrastructure with energy challenges, which would need to send several (not all) of the questions below to each of their nodes.

In this case, please fill the questions you can and let us know whether we can send you a dedicated questionnaire to be distributed to all your nodes to collect information. We will send you the responses related to your RI, which you can use e.g. to report to your governing body (acknowledging ESFRI).

Please don't forget to enter your e-mail at the end of this questionnaire.

○ I would like to receive a dedicated questionnaire.

(3) Q6 = [1]

Q8 - What are the main issues related to energy challenges?

Multiple answers are possible

☐ Lack of finance due to increased energy prices

☐ Conformity with the requirements imposed by the governing body/governments/funders

☐ Insufficient energy supply

☐ Other:

IF (3) Q6 = [1]

Q9 - Can you provide the increase in the energy bill for Nov 2022 compared to Nov 2021 (in EUR and %) and the approximate share of the operational costs that the energy bill represents in the budget of the RI?

Multiple answers are possible

☐ Increase in the energy bill for Nov 2022 compared to Nov 2021 (EUR)

☐ Increase in the energy bill for Nov 2022 compared to Nov 2021 (%)

☐ Share of the operational costs that the energy bill represents in the budget of the RI in 2021 (%)

☐ Comment, if any:

Q10 - If you have introduced/plan to introduce measures to respond to the energy challenges, what are they?

Multiple answers are possible

- ☐ Closing down the facility for a period of time
- ☐ Running the facility at reduced power (e.g. at lower current at synchrotrons)
- ☐ Provision of alternative power sources
- ☐ Reducing heating or air-conditioning of the buildings
- ☐ Delaying or reducing the scope of major projects or construction
- ☐ Other:

Q11 - Which, in your opinion, are the most effective measures for reducing the energy needs of your organisation? (List up to five measures).

_____

Q12 - Do you have a plan on how to address the current energy challenge?

- ○ Yes
- ○ No
- ○ We are preparing it
- ○ Other:

IF (4) Q12 = [1]

Q13 - Have you been asked by your funder/government/governing body/owner to prepare plans to mitigate current risks related to energy supply?

- ○ Yes
- ○ No
- ○ Other:

IF (4) Q12 = [1]

Q14 - Please describe the measures requested. Please use the key keywords, e.g. decreased room temperature, closing down of the facility, etc)

_____

IF (5) Q13 = [1]

Q15 - Who has asked you to prepare the plan?

Multiple answers are possible

- ☐ Funder
- ☐ Government
- ☐ Governing body
- ☐ Owner (e.g. university)
- ☐ Our own initiative
- ☐ Other:

Q16 - Do you have a plan aimed at greening your operations?

- ○ Yes
- ○ We are preparing it
- ○ No
- ○ Other:

IF (6) Q16 = [1]

Q17 - Who asked you to prepare a plan aimed at the greening of your operations?

Multiple answers are possible

- ☐ Funder
- ☐ Government
- ☐ Governing body
- ☐ Owner (e.g. university)
- ☐ Our own initiative
- ☐ Other:

Q18 - Do you face problems with the supply of materials (liquids, solids, gasses)/equipment/parts/data/etc, due to the Russian aggression against Ukraine?

- ○ Yes
- ○ No
- ○ Other comments:

IF (8) Q18 = [1]

Q19 - Can you please provide details about the supply challenges you are facing?

_____

IF (9) Q4 = [2] and Q18 = [1]

Q20 - The questionnaire is not adapted for a distributed infrastructure with supply challenges, which would need to send the question related to the supply challenges to each of their nodes. In this case, please let us know whether we can send you a dedicated questionnaire to be distributed to all of your nodes. We will send you the responses related to your RI, which you can use e.g. to report to your governing body (acknowledging ESFRI). Please don't forget to enter your e-mail at the end of this questionnaire.

○ Please send a dedicated questionnaire

IF (8) Q18 = [1]

Q21 - Any other issues you are facing related to the current energy and supply challenges?

_____

Q22 - By submitting this form, I agree that my responses to the questionnaire can be published.

○ I confirm

Q23 - Please enter you e-mail, so that we can contact you in case we would need more information or a clarification.

_____

ANNEX 2

Energy and Supply Challenges – Questionniare for ESFRI Members

Dear ESFRI colleagues,

Due to the current energy and supply challenges faced by the research infrastructures, ESFRI established a dedicated group which should provide its members (member states, EC and associated countries) with an overview of the situation and possible ways of addressing the challenges.

To be able to deliver on the task, we have designed a brief questionnaire for RIs, which has to be complemented by your views. We kindly ask you to complete a brief survey by clicking on the Next page.

The questionnaire will take about 5 minutes, and we would appreciate receiving your replies by the end of month, February 28th. If you require additional information or clarification of the questions, please feel free to write to us at esfri@fdv.uni-lj.si.

For viewing purposes only, please find the questionnaire in PDF here.

Q1 - On behalf of which country are you responding?

Albania
Armenia
Austria
Belgium
Bosnia and Herzegovina
Bulgaria
Czech Republic
Croatia
Cyprus
Denmark
Estonia
Faroe Islands
Finland
France
Georgia
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Latvia
Liechtenstein
Lithuania
Luxembourg
Malta
Moldova
Montenegro
Netherlands
North Macedonia
Norway
Poland
Portugal
Romania
Serbia

Slovak Republic

Slovenia

Spain

Sweden

Turkey

Ukraine

Other:

Q2 - Are RIs in your country eligible to benefit from general measures to shield consumers from the direct impact of rising prices (e.g. price caps and temporary tax breaks, vouchers and subsidies)?

◯ Yes

◯ No

IF YES

Q3 - Please describe the general immediate measures to shield consumers from the direct impact of rising prices

_____

Q4 - Have you taken any specific immediate measures nationally to support uninterrupted science production, including the continuous delivery of services by the RIs during the current crisis?

◯ Yes

◯ No

IF YES

Q5 - Please describe the measures (e.g. price caps and temporary tax breaks, vouchers and subsidies, supply chain issues). It would also be valuable to know the sources of such funding.

_____

Q6 - Have you asked the RIs:

	yes	no
to introduce specific measures due to the energy crisis?	◯	◯
to reduce energy consumption by a certain % ?	◯	◯
to prepare a plan of measures to address the energy and/or supply challenges?	◯	◯
to prepare a plan for the greening of research infrastructure operation?	◯	◯

IF (3) Q6a = [1]

Q7 - You said you introduced specific measures due to the energy crisis. Can you describe them?

_____

IF (4) Q6b = [1]

Q8 - You said you reduced energy consumption by a certain % . Please list the percentage.

___ %

Q9 - Any other comments regarding measures addressing the energy and supply crisis?

_____

Q10 - Countries may also consider mid-term measures that do not necessarily have an immediate impact on the current situation, but will strengthen readiness for possible future shocks and aid the greening of RI operations. Have you introduced, or do you plan to introduce any such measures?

◯ Yes

◯ No

Q11 - Certain RIs will interrupt their services due to energy and supply challenges. What, in your opinion, is the risk of decreasing/interrupting RI services (including research data handling) over a period of time to save energy?

_____

Q12 - Any other comments?

_____

Email - If you wish, you can enter you e-mail, so we can contact you in case we would need more information or a clarification.

(e.g. john@gmail.com)

_____