

RIKEN CENTER FOR SUSTAINABLE RESOURCE SCIENCE

Advisory Council Report 2016

Center for Sustainable Resource Science Advisory Council
August 8-10, 2016

The second RIKEN Center for Sustainable Resource Science (CSRS) Advisory Council meeting was held from August 8-10, 2016 on the RIKEN Yokohama Campus. The 2016 Advisory Council report is based on the comprehensive report of CSRS current activities and future goals (White Paper) provided by Director Dr. Kazuo Shinozaki and on short presentations of core projects and Integrated Research Platforms provided by the Project Directors. The report summarizes the evaluation and recommendations of the CSRS Advisory Council and addresses the CSRS Directors report and future plans as well as the Terms of Reference by President Dr. Hiroshi Matsumoto and Director Dr. Kazuo Shinozaki.

Members of the RIKEN CSRS Advisory Council present at the 2016 meeting

Dr. Wilhelm Gruissem ETH Zurich, Switzerland	(Chair, Plant Biotechnology)
Dr. Hirokazu Arimoto Graduate School of Life Sciences, Tohoku University	(Chemical Biology)
Dr. Dirk Inzé VIB Department of Plant Systems Biology, Ghent University	(Plant Science)
Dr. Minoru Isobe Professor Emeritus, Nagoya University	(Chemical Biology)
Dr. Kenichiro Itami Director, WPI Institute of Transformative Bio-Molecules, Nagoya University	(Chemistry)
Dr. Peter Kündig Professor Emeritus, University of Geneva, Switzerland	(Chemistry)
Dr. Naoko Nishizawa Research Institute for Bioresources and Biotechnology, Ishikawa Prefectural University	(Plant Science)
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Executive Summary

Since the review in 2014 the RIKEN Center for Sustainable Resource Science (CSRS) has demonstrated the feasibility of merging plant science, catalytic chemistry and chemical biology into a powerful and visionary institute with strong potential of international leadership in innovative interdisciplinary research and novel synergistic approaches. Based on its scientific strength and frontier technologies, CSRS is in an excellent position to address key societal challenges. Full realization of the potential requires further strategic planning as well as new resources for strengthening catalytic chemistry and chemical biology to support increasing synergistic interactions. CSRS is a RIKEN flagship and hub for technology and innovation with enormous potential and a bright future. But as already recommended in the last report, CSRS scientists must now fill their Future Plan starting in 2018 with medium- and long-term strategies as well as vision and aspiration. They are encouraged to develop a plan that embraces entrepreneurship and creates the basis for truly disruptive and game-changing research and technologies.

General Comments and Recommendations

CSRS was started in 2013 by merging RIKEN plant scientists from the Plant Science Center located on the Yokohama campus with chemists and chemical biologists from the Advanced Science Institute located on the Wako campus. In 2015 CSRS also integrated the Biomass Engineering Program and Drug Discovery Platform of the former Research Cluster for Innovation. This has created a unique synergistic center with nearly 40 research groups working at the interface of plant biology, catalytic chemistry and chemical biology to develop novel scientific approaches. They represent an enormous potential of global leadership in solving key societal problems through innovative research and development towards the sustainable use and production of resources. The 2016 report of the Advisory Council is therefore reflecting on the 2014 report when CSRS was first evaluated and further emphasizes the recommendations that were made at that time. Since then CSRS has demonstrated the feasibility and potential of merging different disciplines to address emerging global challenges. This accomplishment should serve as an example of inspiring interdisciplinary research also in other RIKEN institutes. There is no doubt that CSRS is clearly one of the RIKEN flagship centers. Its mission and aspiration are central to RIKEN's mission of delivering innovation to Japan and the world.

CSRS scientists are currently located on the RIKEN Wako and Yokohama campuses. For historical reasons, Wako group leaders have permanent contracts while most Yokohama group and team leaders have 5-year renewable contracts with a maximum contract length of 10 years, after which they have to find employment elsewhere. This discrepancy in job security is causing tension among the CSRS scientists, especially considering the generally scarce employment opportunities in Japan's universities and commercial sectors for even excellent and productive scientists. Moreover, scientists with limited term contracts are less likely to engage in high-risk but also high-reward projects and rather pursue research that leads to publications quickly to strengthen their position in a competitive employment environment. Although RIKEN is currently changing its employment system to increase the number of long-term employment opportunities, it is unlikely that all scientists with 5-year contracts can be moved to permanent positions, nor is this desirable. RIKEN and CSRS should have an employment system that can offer attractive long-term positions to top world-class scientists while maintaining the flexibility to respond to changing societal needs and emerging new and promising scientific fields. This requires an open competitive international

recruitment process and intensive mentorship of RIKEN's young scientists to prepare them for independent academic or industrial careers and to help them identify employment opportunities outside of RIKEN. CSRS is making efforts in placing scientists in leading positions also in overseas institutions and universities, such as the Max-Planck-Institution in Germany and the University of Toronto. The Advisory Council strongly encourages CSRS to continue and even step up these efforts. But effective leadership and management of the CSRS program sometimes also requires difficult decisions to phase out less productive scientists and projects that are no longer aligned with the CSRS mission, goals and strategic re-investments to strengthen and expand areas of critical importance to further growth.

Since the 2014 review CSRS has made good progress in building novel programs and interdisciplinary research projects that take advantage of the expertise available in the center to transform Japan into a green and sustainable society that is based on low carbon emission, smart energy management, and resource-efficient crop production for food and feed. These efforts are currently focused on new approaches for carbon utilization (led by Dr. Kazuki Saito), nitrogen utilization (led by Dr. Ken Shirasu), metal element utilization (led by Dr. Zhaomin Hou) and an integrated research platform for sustainable resource development (led by Dr. Hiroyuki Osada and Dr. Kazuki Saito). The Biomass Engineering Program (led by Dr. Minami Matsui), the Drug Discovery Platforms (led by Dr. Minoru Yoshida and Dr. Hiroyuki Osada), and the Technology Platform (led by Dr. Hiroyuki Osada) continue as Divisions in CSRS with their own budgets. Within these programs CSRS is making strong progress in merging plant science, catalytic chemistry and chemical biology into a synergistic center. RIKEN CSRS together with the World Premier Institute of Transformative Bio-Molecules (ITbM) at Nagoya University represent a unique and powerful concentration of excellent scientists in Japan working at the frontier of small molecule discovery and applications to plants and human health. CSRS must take advantage of this unique strength and lead the world in developing transformative and disruptive technologies that will provide sustainable solutions for national and global societal needs.

The Advisory Council applauds the continued excellence of CSRS research and efforts to establish interdisciplinary projects across the core CSRS scientific fields. Results from several CSRS projects are receiving national and international attention, such as the splitting of atmospheric nitrogen at room temperature or the utilization of manganese oxides for efficient water splitting at neutral pH. These breakthroughs will have significant implications for the environmentally costly production of fertilizers and new types of CO₂-neutral fuels. Similarly, the development of novel copper-catalyzed CO₂ fixation chemistry by CSRS scientists for highly selective multicomponent coupling to novel cyclic lithium borocarbonate ion pair compounds could have strong potential for application as high-performance electrolytes for lithium-ion batteries. Plant scientists have identified high-affinity transporters for efficient uptake of nitrogen and continue to make progress on developing drought-tolerant crops. Similarly, the recent discovery of small molecules that can either increase or inhibit plant immunity have enormous potential for agriculture and facilitating our understanding how plants defend themselves against pathogens and chewing insects that cause enormous damage to crops. Thus, CSRS discoveries will help to reduce the environmental footprint of agriculture by reducing irrigation as well as fertilizer and pesticide applications. Scientists in the CSRS Biomass Engineering Division have developed technology for biopolymer production that is already used in commercial production by Kaneka Corporation. They are also engineering biosynthetic pathways for increased metabolic efficiency, which has significant potential for large-scale production of rubber, for example. CSRS chemists are driving the fields of new functional polymers as well as nanoparticle and earth abundant metal catalysts that have potential for opening new markets, in drug development or for large-scale industrial production processes. Drug development will also profit from new efficient methods developed for site selective trifluoromethyl group introduction into

molecular scaffolds. Together, these and other accomplishments show the continued excellence and high output of CSRS core research programs as well as first promising results from interdisciplinary research. RIKEN plant biology, catalytic chemistry and chemical biology continue to maintain their high rankings in Japan and internationally, as exemplified by publications in top journals, numerous awards, and the fact that in 2015 eight of the 15 highly cited RIKEN scientists were in CSRS.

The Advisory Council finds that since the 2014 report CSRS has made good progress in integrating plant science, catalytic chemistry and chemical biology while maintaining core strength and high scientific output. However, the integration is not yet complete and requires further strategic planning and prioritization of targeted investments to fully realize the interdisciplinary research potential. For example, there is emerging evidence of synergistic research efforts between the biomass engineering project, drug discovery and technology platforms. But there is still a huge and unexploited potential for breaking open new fields. Currently plant scientists are located on the Yokohama campus while most chemists and chemical biologists are on the Wako campus. While RIKEN has made a new building available on the Wako campus to facilitate interdisciplinary research, this is only a stop-gap solution. Ideally, all CSRS research groups should be located in the same building, or at least on the same campus. This requires infrastructure planning and considerable new investments. The Advisory Council understands and appreciates that this might be difficult to realize at present. In the short term, CSRS and the RIKEN administration should therefore engage in further strategic planning to maximize synergistic interactions among scientists by providing significant financial incentives for collaborative interdisciplinary research projects. This should include strong incentives for research groups to relocate between the Wako and Yokohama campuses in order to achieve strategic mixing between the different disciplines. Considering that the CSRS budget has been essentially flat for the last three years and that the Biomass Engineering, Drug Discovery and Technology Platform Divisions maintain their own separate budgets, facilitating interdisciplinary research will require prioritization of current research projects and strategic planning, changes in budget allocations, and additional new resources from the RIKEN administration. In addition, CSRS should implement a strong mentorship and co-supervision program to train young researchers in interdisciplinary research.

As explained in the 2014 report, CSRS has a great potential of becoming a hub for science and technology innovation in the world. The integration efforts have already shown good progress in delivering solutions to societal needs. But the CSRS leadership must now engage in a more effective program development and strategic planning that includes the participation of all research group and team leaders. Together they must establish clear and transparent criteria for prioritization of research projects. The Advisory Council agrees that the CSRS Future Plan for 2018-2023 is a good starting point for strategic planning but recognizes several areas requiring critical attention.

The CSRS Strategic Plan should have a clear vision for the long term and a convincing forward strategy that explains its mission as well as expected milestones and deliverables that scientists wish to achieve in the next 5-10 years. The CSRS leadership should formulate 2-3 flagship projects with high visibility and societal impact. Catalytic chemistry and chemical biology must have central and integrative roles in CSRS to drive the understanding of biological processes and to develop new enabling technologies, efficient catalytic processes, and bio-factories with low burden on environment and society. Chemists and chemical biologists already provide critical support for interrogation of biological problems, but rather than a service this must become truly synergistic and interdisciplinary research co-operations with the plant scientists. To meet the increasing demand of chemical expertise requires an expansion of personnel and resources in catalytic chemistry and

chemical biology, including the hiring of new group leaders that work at the interface of chemistry and biology.

As a new interdisciplinary center, CSRS is in a strong position for interactions with other RIKEN Centers, such as the Biological Resource Center (BRC), Quantitative Biology Center (QBIC) and the Center for Advanced Integrated Intelligence Research (CAII), but also with the technology platforms in the Center for Life Science Technologies (CLST) and with the Center for Integrative Medical Sciences for food- and disease-related research. The Strategic Plan should explain how research collaborations with these RIKEN Centers contribute to the CSRS mission.

Together, CSRS needs to better highlight current strength and discoveries, especially in framing promising future research areas with high impact for society such as:

- Healthy and stress-tolerant high-yielding crops that can cope with climate change
- Fertilizer- and water-efficient crop plants to reduce the ecological footprint of agriculture
- Environmentally friendly catalytic oxidation-, carbon dioxide- and atmospheric nitrogen-chemistries
- Novel genome engineering technologies for molecular breeding of novel traits
- Creative pathway engineering for biological starting material to reduce the reliance on fossil fuels
- Using green biomass for new bio-based polymers that save resources of the earth
- Utilization of natural product libraries to understand plant (and animal) biological processes as well as for discovery of new antibiotics and other compounds for human health

The CSRS strategy plan should also provide an international perspective of the Center's direction, explain how future plans are aligned with RIKEN and government strategies, explain how translational research will be facilitated, and provide convincing plans for technology transfer (national and international, including concepts for start-up companies), as well as communication and outreach efforts. The 2016 White Paper lists numerous national and international as well as inter-ministry research collaborations. These collaborations are useful in creating synergies and perhaps also in inspiring innovation at the government levels. However, the Advisory Council recommends that collaborations should be prioritized to fit the CSRS mission and effectively contribute to strategic outputs. CSRS takes advantage of the RIKEN Cluster for Industry Partnership through RIKEN's Business Development and Promotion offices. To date, these efforts have resulted in translational collaborations and larger-scale industrial application of CSRS technology. However, the RIKEN and CSRS leaderships should also foster entrepreneurship and encourage especially young scientists to pursue their inventions in start-up companies that if successful could become interesting to industry. This requires risk-taking, but with strong mentorship and RIKEN support more scientists might be willing to start their own companies. To promote interactions with industry, CSRS should consider a program for industry researchers to spend time at RIKEN for training in new cutting-edge technologies that are being developed by CSRS scientists.

In summary, the CSRS Advisory Council remains enthusiastic in supporting RIKEN and CSRS for their visionary approach of merging plant sciences, catalytic chemistry and chemical biology into a synergistic center with great potential for innovative research and disruptive technology development. CSRS has all the ingredients for success that with decisive leadership, effective program management and appropriate financial support (including new resources to strengthen chemistry and chemical biology) will translate into important solutions for societal and global challenges.

Recommendations on Terms of Reference (President Dr. Hiroshi Matsumoto)

The Advisory Council reviewed the current accomplishments and future directions of CSRS with respect to the terms of reference provided by RIKEN President Dr. Hiroshi Matsumoto and CSRS Director Dr. Kazuo Shinozaki. Overall, CSRS current operations are strong and contribute to the center's success. Future planning is forward looking but needs a longer-term vision and prioritization of research projects and expected milestone achievements

TOR 1: CSRS research achievements, human resources, focus and future directions

Research in CSRS is excellent with high visibility and impact. Most of the research groups are well recognized nationally and internationally as leaders in their respective fields. CSRS is making strong progress in merging three disciplines (plant science, catalytic chemistry and chemical biology) into a synergistic center. Based on this synergy CSRS is expected to create novel scientific approaches. While plant science is strongly positioned in CSRS, full integration and exploitation of synergies requires strengthening of catalytic chemistry and chemical biology by increasing human and financial resources. The current physical separation of plant science and chemistry/chemical biology on two campuses is not conducive to close interdisciplinary research collaboration. If circumstances currently do not permit consolidation of CSRS on one RIKEN campus, then efforts should be made to mix research on both campuses. Considering the unique opportunities created by strengthening and expanding interdisciplinary research, CSRS should make it its policy and mission to address critical societal challenges. In this context CSRS should focus its research activities on crop improvement in face of climate change, development of new bio-based materials that reduce the environmental footprint, innovating energy-efficient catalytic utilization of abundant atmospheric resources such as CO₂ and N₂, and application of innovative catalytic chemistry and chemical biology to understand plant (and animal) processes.

TOR 2: Re-evaluations of the centers in operation more than 10 years

Not applied to CSRS

TOR 3: RIKEN Initiative for Scientific Excellence

CSRS clearly has achieved scientific excellence and must be considered one of RIKEN's flagship centers. The mission of CSRS is fully aligned with the RIKEN mission Initiative for Scientific Excellence by serving society through innovative research and international leadership in addressing global challenges.

3.1 Research management model

CSRS is managed by the Director, three Deputy Directors, and five Group Directors and Division Directors. The Director and Deputy Director form the core management team who decides on strategic research directions with input from the Group and Division Directors. Research Group Leaders, Research Team Leaders and Research Unit Leaders are regularly informed by the Director about administrative decisions and planning. However, prioritization, management and strategic future planning for maximizing research and development results could strongly benefit from a broader involvement of the younger scientists who are the force responsible for excellent, high-impact scientific achievements and international visibility of CSRS.

The CSRS budget is currently allocated to research groups by the Director. The Biomass Engineering, Drug Discovery and Technology Platform Divisions maintain their own separate budget. There is opportunity to centralize the budget in CSRS and establish transparent criteria and strategic

priorities by which funds are allocated to core projects and individual research groups. CSRS should provide attractive internal financial incentives for true interdisciplinary collaborations among the plant scientists, chemists and chemical biologists to facilitate their integration. These incentives should be attractive enough to motivate a stronger mixing of scientists and research groups between the Wako and Yokohama campuses. At the same time CSRS urgently needs additional RIKEN resources for strengthening human resources in chemistry and chemical biology to effectively support interdisciplinary research. CSRS scientist are highly successful in securing external research funds, which is especially impressive considering the limited availability of competitive funding and the prevailing view in the research community that RIKEN scientists have enough internal support.

3.2 Leading the world in achieving new research and development results

There are many examples already that document pioneering research at CSRS, also indicated by an impressive number of publications in top journals, a strong patent portfolio, effective translational research, and eight scientists who are among the most highly cited scientists in the world. CSRS is now reporting first results from innovative interdisciplinary research collaborations that were facilitated by integrating plant science, catalytic chemistry and chemical biology. Full realization of the CSRS potential requires further longer-term strategic planning, programmatic prioritization, strong synergistic interactions and new resources.

3.3 A hub for science and technology innovation

CSRS scientists have built an impressive number of national and international research collaborations, partly based on the cutting edge technology platforms that are important national resources. Supported by the RIKEN Cluster for Industry Partnership, CSRS scientists have also established industry contacts that are now becoming translational collaborations and larger-scale industrial applications of CSRS technology. Emerging inter-ministry collaborations may also inspire the government of Japan to develop new national research programs. Collectively, these efforts have enormous potential and show that within a short time CSRS has become a hub for science and technology innovation. But they must now be prioritized and aligned with the CSRS mission longer-term strategic planning to maximize impact and success. Fostering entrepreneurship among CSRS scientists to continue development and translation of their research results in spin-off companies will further strengthen the hub function of CSRS.

Because of its interdisciplinary nature, CSRS should develop initiatives and build partnerships with other RIKEN Centers such as BRC, QBiC, CAII, CLST and the Center for Integrative Medical Sciences, to facilitate interdisciplinary research and disruptive technology development not only in CSRS but across RIKEN institutes.

3.4 A focal point for global brain circulation

CSRS is making sincere efforts of recruiting the best national and international scientists, but the current short-term (5-10 year) contracts and limited long-term employment opportunities in RIKEN restrict the pool of top scientists who are attracted to group or team leader positions, despite the world-leading research and infrastructure environments of RIKEN. Nevertheless, CSRS continues to do well in hiring excellent young scientists who are highly motivated in building their careers. Nearly half of the CSRS staff members are female, but the recruitment of female scientists into leading positions remains a weak point that must be improved by the CSRS management. Similarly, the appointment of foreign group leaders and postdoctoral fellows continues to lag behind other institutions around the world comparable in size and international visibility to RIKEN.

CSRS continues to invest in research platforms and technologies to strengthen the state-of-the-art research environment. However, such investments must also be based on strategic planning and consultation of all group and team leaders to assure that instruments and technologies support the broadest possible user base, thereby maximizing research outputs.

3.5 Development of world-class leaders in scientific research

Guidance, mentorship and a supportive research environment are key to building successful careers of young scientists. CSRS is doing well in this regard and most of the scientists with limited-term contracts find attractive positions in Japan or in international institutions and universities to continue their career. Nevertheless, CSRS should step up efforts of attracting excellent young scientists through open competitive international recruitment processes. Management should establish an effective mechanism of intensive mentorship of young scientists in CSRS to prepare them for independent academic or industrial careers and to help them identify employment opportunities outside of RIKEN.

Considering its innovative interdisciplinary nature and strong technologies, CSRS should develop a program for industry researchers in which they can be exposed and immersed in new cutting-edge technologies and methods that are being developed by CSRS scientists at the interface of plant science, catalytic chemistry and chemical biology.

TOR 4: CSRS activities towards maximizing RIKEN's achievements

CSRS is clearly one of the RIKEN flagship centers. Its mission and activities as well as current and future achievements are central to RIKEN's mission of innovation for the society of Japan and the world.

Recommendations on Requests from CSRS Director (Dr. Kazuo Shinozaki)

1. CSRS status and operational improvement since the 2014 report

As explained in more detail in the General Comments and Recommendations, CSRS has made good progress in integrating plant science, catalytic chemistry and chemistry while maintaining core strength and high scientific output in the three disciplines. However, the integration is not yet complete and requires further strategic planning and prioritization of targeted investments.

1.1 Status of core research and integrated research projects

There are many examples of exciting and high-impact results from several CSRS core and integrated research projects that are receiving national and international attention. Several are highlighted in the 2016 report and can be found in the presentations of the Group Directors. The Advisory Council remains enthusiastic about the excellence of CSRS research and efforts to establish interdisciplinary projects across the core scientific fields.

1.2 Positioning of integrated biomass engineering project, technology platform area, and drug discovery area

There is convincing evidence of emerging synergistic research efforts between the biomass engineering project, technology platforms, and drug discovery area. But there also is still a huge underexplored and underexploited potential for breaking open new fields. As explained in more detail in the report, realization of this potential requires effective strategic planning and transparent prioritization of research programs.

1.3 International collaboration, collaboration with corporations or other research institutes, and collaboration within the Center

CSRS is making strong efforts of building collaboration and has an impressive list of collaborative research efforts. However, it is important to carefully evaluate and prioritize collaborations in order to strengthen the mission of CSRS.

2. Five-year plan starting from 2018

The CSRS Future Plan for 2018-2023 is a good starting point for further strategic planning. The CSRS Management should include all Team Leaders and Unit Leaders in developing a visionary, innovative and world-leading research program to address societal challenges.