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READEX
Runtime Exploitation of Application Dynamism
for Energy-efficient eXascale computing

D6.6 Updated Report on Dissemination, Communication, Standardization, and exploitation activities

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1.0	31.08.2018	Robert Schöne	Robert Schöne

Contents

Executive Summary

The READEX project had a strong focus on broad dissemination of project results, thereby targeting several important audiences, including potential collaborators and developers within the scientific community, end-users and domain scientists, as well as the broader public. This document describes the dissemination, communication, standardization, and exploitation activities that we performed during the project. We show an overview of dissemination activities in Figure 1. Here each dot represents one or multiple (up to five) activities of the three dissemination domains during a project month. The project partners published 31 articles and papers, including accepted ones. The partners organized and co-organized five workshops and presented READEX posters at 20 conferences and workshops. We also communicated results through the project web page, a Twitter account, and a ResearchGate project. As suggested in the interim review, we used the final phase of the project for exploitation and collaboration, where we collaborated with external partners on tuning their codes and supporting installation at European HPC sites. We also collaborated with other European and national research projects to advertise our tools and combine expertise for related questions. We implemented numerous software components, which are available with non-restrictive Open Source licenses at the READEX github repository[1]. We will use the READEX tool suite in future projects and present it during user trainings. Furthermore, the interfaces we created will spark research activities in other areas.

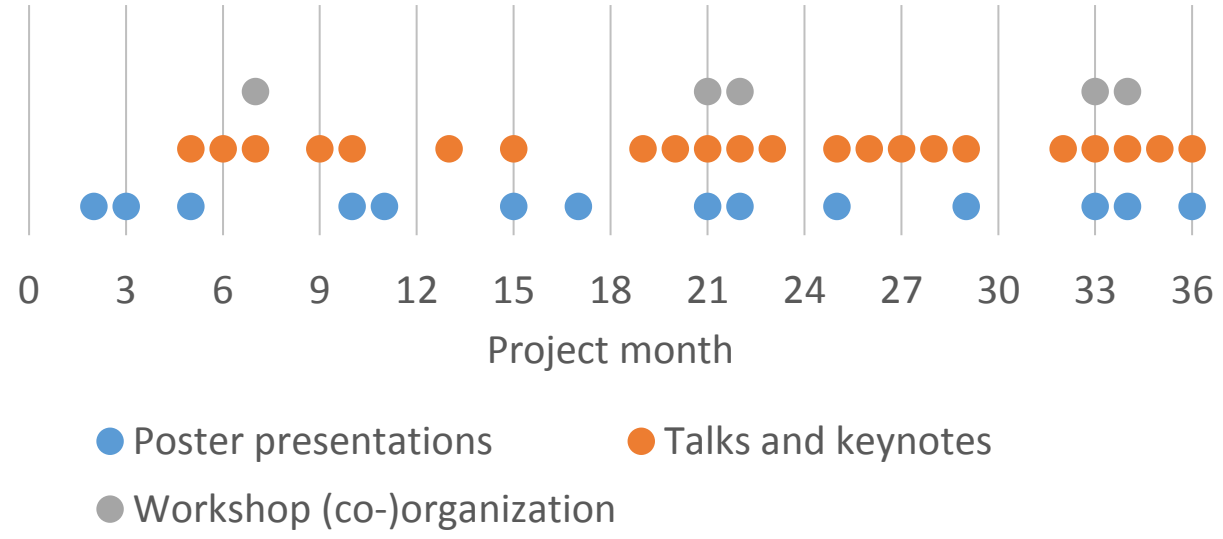

Figure 1: General Overview on Dissemination Activity

[1] https://github.com/readex-eu

1 Dissemination Activities

The READEX project performed several different dissemination activities throughout the lifetime of the project, including scientific publications, posters and talks, the organisation of workshops as well as several communication activities to reach out to the public.

We collect all dissemination material in the project's Sharepoint document repository and the GIT repository. Furthermore, we make it available through the project website. As defined in the Consortium Agreement, any dissemination of results (in any form, including electronic) must:

- Display the EU emblem (with appropriate prominence; except for scientific papers)
- Include the following text:
  "This project READEX has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 671657."

1.1 Publication of Results

The partners in the READEX project publish their specific research results in the form of conference and journal publications. The following publications were published or are accepted for publication in the context of READEX:

- L. Riha, M. Merta, R. Vavrik, T. Brzobohaty, A. Markopoulos, O. Meca, O. Vysocky, T. Kozubek and V. Vondrak; "A massively parallel and memory efficient FEM toolbox with A Hybrid Total FETI solver with accelerator support", *The International Journal of High Performance Computing Applications (IJHPCA)*, 2018 (accepted)
- N. Reissmann and A. Muddukrishna, "Diagnosing Highly-Parallel OpenMP Programs with Aggregated Grain Graphs", *International European Conference on Parallel and Distributed Computing, Euro-Par*, 2018 (accepted)
- P.G. Kjeldsberg, R. Schöne, M. Gerndt, L. Riha, V. Kannan, K. Diethelm, M-C. Sawley, J.Zapletal, O. Vysocky, M.Kumaraswamy, and W.E. Nagel, "Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing", book chapter in "*System Scenario-based Design Principles and Applications*, Springer International Publishing AG (accepted)
- P.G. Kjeldsberg, "READEX gjør dynamiske HPC-applikasjoner energieffektive", ("READEX makes HPC applications energy efficient"), in *Elektronikk*, nr. 10 (accepted).
- V. Nikl, O. Vysocky, L. Riha, J. Zapletal: "Optimal Hardware Parameters Prediction for Best Energy-to-Solution of Sparse Matrix Operations Using Machine Learning Techniques", *INFOCOMP 2018 (ECO-PAR special track)*, Barcelona, 2018
  [Download (Thinkmind)]
- O. Vysocky, J. Zapletal, L. Riha: "A Simple Framework for Energy Efficiency Evaluation and Hardware Parameter Tuning with Modular Support for Different HPC Platforms", *INFOCOMP 2018 (ECO-PAR special track)*, Barcelona, 2018
  [Download (Thinkmind)]
- T. Ilsche, R. Schöne, P. Joram, M. Bielert, A. Gocht, "System Monitoring with lo2s: Power and Runtime Impact of C-State Transitions", *Proceedings of the IEEE Workshop on High-Performance Power-Aware Computing*, 2018

doi: 10.1109/IPDPSW.2018.00114
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- O. Vysocky, J. Zapletal, M. Beseda, L. Riha, V. Nikl, M. Lysaght, V. Kannan, “MERIC and RADAR generator: tools for energy evaluation and runtime tuning of HPC applications”, *HPCSE 2017*, Solan, Czech Republic, 2018
  doi: 10.1007/978-3-319-97136-0_11
- O. Vysocky, M. Beseda, L. Riha, J. Zapletal, V. Nikl, M. Lysaght, V. Kannan, "Evaluation of the HPC Applications Dynamic Behavior in Terms of Energy Consumption*", Proceedings of the Fifth International Conference on Parallel, Distributed, Grid and Cloud Computing for Engineering*, Civil-Comp Press, Stirlingshire, UK, Paper 3, 2017
  doi: 10.4203/ccp.111.3
- M. Sourouri, E.B. Raknes, N. Reissmann, J. Langguth, D. Hackenberg, R. Schöne, P.G. Kjeldsberg, “Towards fine-grained dynamic tuning of HPC applications on modern multi-core architectures”, *Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis*, 2017.
  doi: 10.1145/3126908.3126945
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- T. Ilsche, M. Hähnel, R. Schöne, M. Bielert, D. Hackenberg, “Powernightmares: The challenge of efficiently using sleep states on multi-core systems”, *European Conference on Parallel Processing*, 2017
  doi: 10.1007/978-3-319-75178-8_50
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- T. Ilsche, R. Schöne, M. Bielert, A. Gocht, D. Hackenberg, “lo2s—Multi-core System and Application Performance Analysis for Linux”, *2017 IEEE International Conference on Cluster Computing (CLUSTER).*
  doi: 10.1109/CLUSTER.2017.116
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- A. Chowdhury, M. Kumaraswamy, M. Gerndt, Z. Bendifallah, O. Bouizi, L. Říha, O. Vysocký, M. Beseda, J. Zapletal, “Domain Knowledge Specification for Energy Tuning”, *2nd Workshop on Power-Aware Computing (PACO)*, Ringberg Castle, Kreuth, Germany, 2017.
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- A. Chowdhury, M. Kumaraswamy, M. Gerndt, “READEX Tool Suite for Energy-efficiency Tuning of HPC Applications”, *Proceedings of the Workshop on Software Engineering Methods for Parallel and High Performance Applications at HPDC (SEM4HPC)*, Washington D.C., United States, 2017.
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  doi: 10.1007/978-3-319-56702-0_4
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  [Download] [SAO/NASA ADS]
- J. Schuchart, M. Gerndt, P. G. Kjeldsberg, M. Lysaght, D. Horák, L. Říha, A. Gocht, M. Sourouri, M. Kumaraswamy, A. Chowdhury, M. Jahre, K. Diethelm, O. Bouizi, U. S. Mian, J. Kružík, R. Sojka, M. Beseda, V. Kannan, Z. Bendifallah, D. Hackenberg, and W. E. Nagel, "The READEX formalism for automatic tuning for energy efficiency", *Computing*, 2017.
  doi: 10.1007/s00607-016-0532-7
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- R. Schöne, T. Ilsche, M. Bielert, D. Molka, and D. Hackenberg, "Software controlled clock modulation for energy efficiency optimization on Intel processors", *Proceedings of the 4th International Workshop on Energy Efficient Supercomputing (E2SC)*, Salt Lake City, UT, USA, 2016.
  doi: 10.1109/E2SC.2016.015
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- D. Horák, L. Říha, R. Sojka, J. Kružík and M. Beseda, "Energy consumption optimization of the Total-FETI solver and BLAS routines by changing the CPU frequency" *International Conference on High Performance Computing & Simulation (HPCS)*, Innsbruck, Austria, 2016.
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- V. Hapla, D. Horák, L. Pospisil, M. Cermak, A. Vasatova and R. Sojka, "Solving Contact Mechanics Problems with PERMON" *High Performance Computing in Science and Engineering: Second International Conference*, 2015.
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  doi: 10.1145/2916026.2916028
  [Download][OpenAIRE]
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  doi: 10.1109/CSE.2015.55
  [Download] [OpenAIRE]

1.2 Posters and Talks

Whenever possible, the READEX project partners accept invitations to present posters, e.g., in addition to accepted research papers and at exhibition booths, and to represent the project through talks at conferences and industry forums.

We presented the following posters:

- Poster "Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing", 2015 IEEE 18th International Conference on Science and Engineering (CSE 2015), October 2015.
- Posters presented at IT4I and TUD exhibition booths, SC'15, November 2015.

- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, HiPEAC Conference 2016, January 2016.
- Poster presentation at ICHEC, IT4I, and TUD exhibition booths, ISC’16, June 2016.
- Poster “Energy Consumption Optimization of the Total-FETI Solver and BLAS Routines by Changing the CPU Frequency” HPCS conference 2016, July 2016.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, 9th Nordic Workshop on Multi-Core Computing (MCC2016), November 2016.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, 17th Geilo Winter School: Machine learning, deep learning, and data analytics, January 2017.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, HiPEAC Conference 2017, January 2017.
- Poster “Tools for Application Dynamism Evaluation in Terms of HPC Applications Energy Saving”, HPCSE 2017, May 2017.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, Teratec Forum Research Café 2017, June 2017.
- Poster “READEX”, VI-HPS Anniversary, June 2017
- Poster “READEX”, HPDC 2017, June 2017.
- Poster “Energy Efficient High Performance Computing due to Application Dynamism”, presented at PASC 2017, June 2017.
- Poster “READEX Runtime Exploitation of Application Dynamism for Energy-efficient Computing” at ISC’17 project poster session, June 2017.
- Poster “READEX” presented at womENcourage'17, September 2017.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, presented at HiPEAC Conference 2018, January 2018.
- Poster “READEX: Runtime Exploitation of Application Dynamism for Energy-efficient eXascale computing” at European HPC Summit Week 2018, HPCAFE Workshop, May 2018.
- Poster “Runtime Exploitation of Application Dynamism for Energy-efficient Exascale Computing”, presented at Teratec Forum 2018, June 2018.
- Poster “Exploiting Inter-Phase Application Dynamism to Auto-Tune HPC Applications for Energy-Efficiency” ICPP2018, August 2018.
- (planned) Poster „READEX Evaluation“ Fakultät für Informatik, TU München, November 2018.

We presented READEX technology and result in the following talks, lectures, tutorials, and keynotes:

- Talk “Introduction of READEX project and IT4I activities” at HiPEAC conference 2016, January 2016.
- Keynote presentation at 2nd International Conference on Green High Performance Computing, February 2016.
- Talk “Tools for Assessing and Optimizing the Energy Requirements of High Performance Scientific Computing Software” at Gemeinsame Jahrestagung der Deutschen Mathematiker-Vereinigung und der Gesellschaft für Angewandte Mathematik und Mechanik, March 2016.
- Talk “Autotuning of MPI applications using PTF” at HPDC’16 SEM4HPC, May 2016.

- Talk “The READEX project for Dynamic Energy Efficiency Tuning” at HPDC’16 SEM4HPC, May 2016.
- Talk “The energy consumption optimization of the FETI solver” PASC16 conference, June 2016.
- Talk “ Optimizing the Energy Efficiency of High Performance Scientific Computing Software” GAMM CSE Workshop 2016, Sept 2016.
- Talk “ Manual and Automatic Energy Tuning for HPC Codes” HPC-Status-Konferenz der Gauß-Allianz 2016, November 2016.
- Talk "READEX: Linking Two Ends of the Computing Continuum to Improve Energy-efficiency in Dynamic Applications", DATE 2017, March 2017.
- Talk “Detecting Memory-Boundedness with Hardware Performance Counters”, ICPE 2017, April 2017
- Talk “READEX: A software tool-suite for achieving energy efficiency at extreme scale”, European HPC Summit Week 2018, HPCAFE Workshop, May 2017.
- Talk “Evaluation of the HPC Applications Dynamic Behavior in Terms of Energy Consumption”, 5th International Conference on Parallel, Distributed, Grid and Cloud Computing for Engineering, May 2017
- Talk “MERIC and RADAR generator: tools for energy evaluation and runtime tuning of HPC applications” HPCSE 2017, May 2017
- Talk “READEX”, PRACE-5IP Exascale Workshop, June 2017.
- Tutorial “Hands-on Practical Hybrid Parallel Application Performance Engineering”, VI-HPS, June 2017.
- Talk "READEX Tool Suite for Energy-efficiency Tuning of HPC Applications", Software Engineering Methods for Parallel and High Performance Applications (SEM4HPC), HPDC2017, June 2017.
- Talk “READEX Runtime Exploitation of Application Dynamism for Energy-efficient Computing”, ISC workshop ENA-HPC, June 2017.
- Talk “Domain Knowledge Specification for Energy Tuning”, PACO, July 2017.
- Talk "Design-Time Analysis for the READEX Tool Suite", Parco, September 2017.
- Talk at 26th VI-HPS Tuning Workshop, October 2017.
- Talk “The IT4INNOVATIONS effort in READEX and Antarex H2020 projects”, HiPEAC ACS 2017, October 2017.
- Talk “READEX Update and Results” 8th Annual Workshop for the Energy Efficient HPC Working Group at SC’17, November 2017.
- Talk “READEX - A Tools-guided Approach for Improving the Energy Efficiency of HPC Applications” at PRACE booth, SC’17, November 2017.
- Talk "Towards Fine-Grained Dynamic Tuning of HPC Applications on Modern Multi-Core Architectures", SC’17, November 2017.
- Talk “Machine Learning for Energy Efficiency”, BoF Machine Learning for Parallel Performance Analytics, SC’17, November 2017
- Talk "Towards Aggregated Grain Graphs", presented at 4th International Workshop on Visual Performance Analysis - VPA 2017, SC’17, November 2017.
- Invited keynote “On the Asymptotic Behavior of Solutions to Fractional Order Differential Equations” MANNA 2017, December 2017.

- Talk “Design-time Analysis for Energy Efficiency Tuning of HPC Applications” at Informatik Kolloquium, Universität Salzburg, December 2017.
- Invited talk “On the Principle of "Fractionalization" in Mathematical Modeling”, Numerical Analysis Seminar, Texas A&M University, December 2017.
- Talk "Dynamic tuning of the energy efficiency of applications with the READEX toolsuite" in NovelHPC: Beyond Exascale: Workshop on Novel HPC Architectures, HiPEAC 2018, January 2018.
- Talk at 27th VI-HPS Tuning Workshop, April 2018.
- Invited talk „Klassische und unkonventionelle Ansätze für die numerische Integration fraktionaler Ordnung.“ Kolloquium des Instituts für Nichtlineare Mechanik, Universität Stuttgart, May 2018.
- Talk “READEX: Runtime Exploitation of Application Dynamism for Energy-efficient eXascale computing” European HPC Summit Week 2018, HPCAFE Workshop, May 2018.
- Talk “READEX” at Power Stack Workshop, June 2018.
- Invited keynote lecture “Fast Algorithms for the Approximate Computation of Riemann-Liouville Integrals of noninteger order” Structural Dynamical Systems, June 2018.
- Talk “Towards Energy-Efficient Exascale Computing: A Use-Case Applying READEX to Alya”, at the PRACE booth in ISC 2018, June 2018.
- Talk “Performance and AI Machine Learning and HPC at TU Dresden”, BoF Artificial Intelligence and Performance Analysis/Optimization, SC’18, June 2018
- Talk “READEX – Tools for Automatized Power Saving in HPC”, ISC workshop EETHPC, June 2018.
- Talk “READEX Design Time Analysis for Dynamic Energy Efficiency Tuning” at Scalable Tools Workshop, July 2018.
- Talk “High Performance Computing Applications Dynamism Evaluation for Energy Tuning”, IHPCSS18, July 2018.
- Talk “READEX: A Tool-Suite for Dynamic Energy Tuning” Lawrence Livermore National Laboratory, July 2018.
- Talk “A Simple Framework for Energy Efficiency Evaluation and Hardware Parameter Tuning with Modular Support for Different HPC Platforms”, INFOCOMP 2018 (ECO-PAR special track), July 2018.
- Talk “Leveraging Inter-Phase Application Dynamism for Energy-Efficiency Auto-Tuning”, PDPTA'18, August 2018.

1.3 Organization of Workshops

Workshops are used to spark interest in the topic of dynamic code auto-tuning and tuning for energy-efficiency. At the same time, they are used as a platform to present the progress of the project.

The first workshop we organized was the *International Workshop on Dynamic Code Auto-Tuning,* held in conjunction with the International Symposium on Code Generation and Optimization 2016 (CGO’16) on March 12, 2016. We used this to spark interest in the topic of energy efficiency in general through invited speakers and to present first results of the READEX project. Afterwards, we used the ISC conference and the EXDCI HPC Summit as occasion to gather with like-minded people, and present and promote READEX. A list of workshops, which we organized and co-organized is given in *Table 1: (Co-) organised* workshops.

Table 1: (Co-) organised workshops

Workshop	Project Month	Activities
CGO'16	7	Organization of the *International Workshop on Dynamic Code Auto-Tuning*
EXDCI HPC Summit'17	21	Co-organization of *HPCAFE* workshop
ISC'17	22	Co-organization of *ENA-HPC* workshop
EXDCI HPC Summit'18	33	Co-organization of *HPCAFE* workshop
ISC'18	34	Organization of the *EETHPC* workshop

1.4 Future Dissemination Events

With the final READEX tool-suite being available at the end of the project, we plan to publish further results during upcoming events to keep the interest for the project alive. This includes the publication of final results and poster and flyer presentations at SC'18.

2 Communication Activities

We regard communication with the public as a high-priority goal of the READEX project. We used various means to maximize public engagement, including the creation of dissemination material, a public website, a public mailing list, presence on social media platforms, and press releases. We summarize the measures in *Table 2: Communication activities in the READEX project*.

Table 2: Communication activities in the READEX project

Platform	Target Audience	Usage
Public project website	General public, including potential users, research organizations, industry	Provide up-to-date project information, attract attention to the project, provide contact information, distribute press releases
Public project mailing list	Potential users, research organizations, industry	Communicate project updates, manage direct communication with interested entities, distribute press releases
Social media	General public, including potential users, research organizations, industry	Communicate project updates, manage direct communication with interested entities, spark public interest in and awareness of the project
Press releases	General public, research and industry	Communicate regular project updates and final results to a broad audience, beyond the READEX community and interested users

2.1 Public Website

The READEX project has created a public website that contains important information on the project, e.g., a summary of the research goals and technologies used, the partners and external advisory board

members as well as upcoming events and news. Furthermore, it lists the project's publications and provides access to the project's dissemination material, e.g., posters and flyers. We presented the structure and details of the website in deliverables D6.1 and D6.2. We updated the website to be more software and result centric, according to the comments of the first review: Now, the website also hosts the latest software version, a tutorial video and examples. We updated the software components regularly in the final six months of the project.

2.2 Dissemination Material

The READEX project has created dissemination material that is handed out at talks, workshops, and conferences, e.g., at the partners' booths at the Supercomputing Conference (SC) and International Supercomputing Conferences (ISC). This material includes flyers and posters that contain information on the project. The material is also available for download on the public website.

2.3 Social Media Activity

Social media is considered an important factor in the struggle to achieve attention among stakeholders as well as potential collaborators and end-users. The READEX project has created a Twitter account (@readex_eu) that we use to inform followers. Since September 2016, we also announce publications via the READEX ResearchGate project[2]. Currently, the Twitter account has 147 followers, which meets our expectations. The ResearchGate project attracted 23 followers.

2.4 Press Releases

We used press releases to reach out to the general public and interested end-users. This also includes news articles in newsletters published by the READEX consortium members. The READEX project has released the articles in the following member newsletters:

- The Gauß-Allianz newsletter: https://gauss-allianz.de/files/infoletter/GA-Infobrief_38.pdf
- The newsletter of the Center for Information Services and High Performance Computing (ZIH) of the Technische Universität Dresden: http://tu-dresden.de/die_tu_dresden/zentrale_einrichtungen/zih/publikationen/zih_info/zih_info_96
- The IT4Innovations newsletter: http://www.it4i.cz/wp-content/uploads/2015/10/newsletter-2015-01.pdf
- IHK Innovations- und Umweltnachrichten: https://www.braunschweig.ihk.de/uploads/tx_tspagefileshortcut/IuU_NewsletterGNS_2016-04-27.pdf
- The newsletter of the Center for Information Services and High Performance Computing (ZIH) of the Technische Universität Dresden: https://tu-dresden.de/zih/ressourcen/dateien/publikationen/zih_info/dateien/mai18.pdf

[2] https://www.researchgate.net/project/READEX

3 Standardization, Collaboration, and Exploitation Activities

A major objective of READEX was user uptake. To increase it and provide support, we contacted external sites and provided support for installation and usage of READEX software components on their systems, beginning in project month 28. We used a survey form that asked for available software interfaces for hardware parameter access and energy measurement, and possible codes that we could support. Unfortunately, the response rate was low and the initially supported hardware interfaces are not available on many production systems. The latter is mainly due to stability concerns. We therefore contacted developer teams within the centres and supported the installation of READEX on test clusters on the respective sites. As soon as the administrators of the HPC systems enable the software interfaces for the access, the administrators can merge the READEX installations to the full HPC system. Furthermore, we added support for energy measurement and hardware parameter control interfaces of other hardware vendors to comply with the diverse hardware and software environments. Figure 2 shows HPC sites where READEX technology is installed. Green stars mark sites with June ’14 Top500 installations where READEX software is installed. Sites with a June ’18 installation are framed red. Yellow stars indicate that the installation process started. Orange stars mark HPC sites, where installation is planned in the near future. Blue stars mark non-Top500 installations, which use READEX technology but not necessarily the whole tool suite. Despite one could consider Score-P 4.0 to be partially READEX technology (see Section 3.2), we do not count standard Score-P installations here.

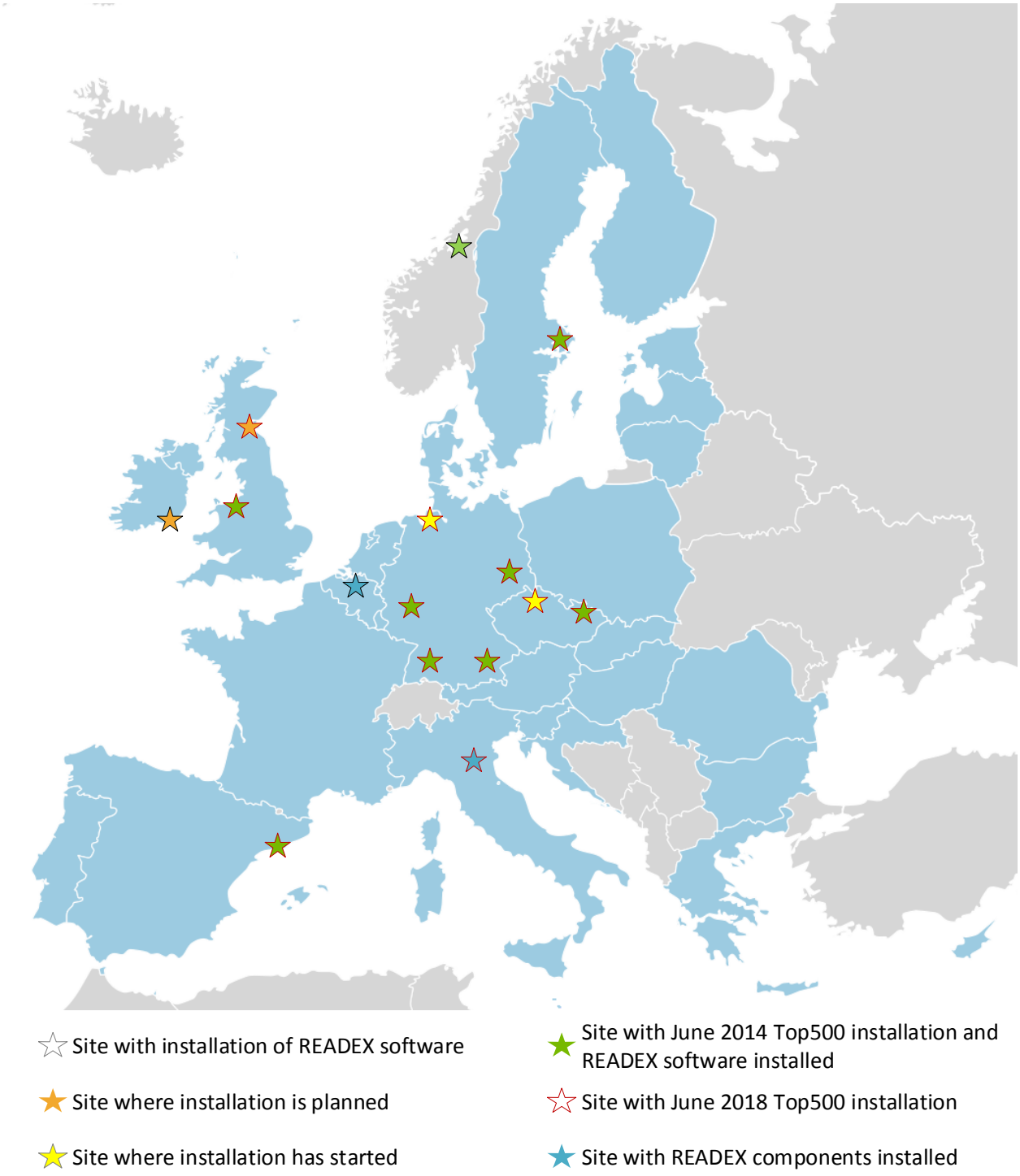

Figure 2: Location of European HPC sites where READEX technology is installed or installation is planned. (See Section 3.8)

3.1 READEX Regular Beta Prototypes and Release Candidate

Since March 2018, we provided Beta prototypes at the project website. We updated these in regular intervals to fix existing issues. We released a pre-release-candidate in the beginning of August 2018 and the final release-candidate in end of August 2018.

3.2 Collaboration with the Score-P Project

Score-P is one of the core software components of READEX. During the project, the partners TUD and TUM actively contributed to the software by fixing bugs and implementing features that are used in the READEX context but can also be used by other projects. The newly developed substrate interface enables programmers to efficiently use the instrumentation from Score-P for any other purpose, e.g., debugging or performance analysis. We show some examples in [1], where we re-use the interface for performance monitoring and balancing-based energy efficiency tuning. The balancing-based tuning plugin was able to ***save up to 19.3 % energy*** for the weather forecast simulation tool COSMO SPECS running at 384 MPI ranks [2]. The interface is part of the current Score-P version 4.0, used in other projects, maintained by the community, and was already extended by programmers at JSC. Furthermore, the interface was used in two Bachelor theses and is used in a Dissertation.

The READEX Programming Paradigm uses existing Score-P interfaces when possible. Therefore, a single code annotation can be used manifold. In addition to the automatized tuning with READEX, users can also easily profile or trace their application for performance debugging, load balance inspection, or energy efficiency analysis.

3.3 Generic Libraries for Energy Measurement and Hardware Parameter Access

One major problem for a general acceptance of energy efficiency tuning tools is that there is not one common interface for reading energy values or toggling hardware parameters, but multiple ones. To support a broad range of systems, we extended our software to use the common interfaces and newer processors (e.g., Intel Skylake and AMD Zen). The sources are available publicly on github[3] and on the project site. This enables other projects, which are not interested in tuning for energy efficiency, but in creating energy models, to use our software. Examples for such groups are the DFG SFB HAEC (see next section) and researchers at IMEC.

3.4 Collaboration with the HAEC Project

We supported the DFG SFB 912 HAEC[4] with the creation of a new performance and energy efficiency monitoring tool `lo2s` [3]. We used this tool to find and analyse a peculiarity within the Linux kernel [4], which resulted in a fix that is part of Linux kernel 4.17. According to external sites, the new implementation reduces idle power consumption by 10% [5]. In Europe, the annual power consumption of data centres is between 72.5 and 100.0 TWh [6]. If we assume that 10% of that energy is spent during idle periods (7.25-10.0 TWh/a) and the average cost for energy in Europe is 0.112 €/kWh [7], ***80-112 M€ savings can be saved annually*** by upgrading to the new kernel.

[3] https://github.com/readex-eu/libfreqgen https://github.com/tud-zih-energy/x86_energy
[4] http://gepris.dfg.de/gepris/projekt/164481002

3.5 Collaboration with the ANTAREX Project

We have collaborated with the ANTAREX project[5] on different issues. We evaluated the following applications or application kernels using READEX methodology:

- *SMURFF* – In a collaboration with IMEC, we investigated the highly optimized and parallelized framework for Bayesian Matrix and Tensors Factorization SMURFF[6]
- *Betweenness* – In an internal collaboration at IT4I, we investigated C++ implementation[7] of Betweenness algorithm according to U. Brandes: On Variants of Shortest-Path Betweenness Centrality and their Generic Computation
- *Probabilistic Time-Dependent Routing kernel* – In another internal collaboration with IT4I, we investigated this algorithm

We also held different telephone conferences with IMEC and supported them with installing Score-P and power measurement libraries that we developed in the READEX project. IMEC used the infrastructure to analyse the influence of workloads on DRAM power consumption. Furthermore, we are currently developing a Score-P Metric Plugin for EXAMON[8]. This plugin will enable READEX on systems where such a measurement infrastructure exists.

3.6 Collaboration with the Special Interest Group on Scenario Driven Design for Embedded Systems (ScenarioSIG)

Throughout the project time frame we regularly communicated and presented READEX at workshops organized by the ScenarioSIG. One of the main SIG organizers, Professor Francky Catthoor, is also on the External Advisory Board of READEX. Currently, the ScenarioSIG prepares a Springer book on System Scenario Based Design, which is in its final phase before printing. One of the chapters in this book is dedicated to the READEX project, which will enable further dissemination of project results to the embedded community.

3.7 Collaboration with the Energy Efficient High Performance Computing Working Group (EEHPCWG)

In collaboration with the EEHPCWG, we presented READEX at the Supercomputing Conference 2017. Furthermore, we collaborated on the organization of the Energy Efficient Tools for HPC workshop 2018[9].

3.8 Collaboration with External Sites and Installation Support

During the final months of the project, we collaborated with several external HPC sites and supported them with installing and using READEX software components. In the first review, we announced that we would visit sites of the EAB. To prepare this, we send a survey to the EAB in project month 27, discussed this in the EAB meeting in project month 29. Since no external partner picked up the idea of site visits, we

[5] http://www.antarex-project.eu/
[6] https://smurff.readthedocs.io/en/latest/
[7] https://code.it4i.cz/ADAS/betweenness
[8] https://github.com/readex-eu/scorep_plugin_examon
[9] http://eethpc.net

decided to use remote access and emails to support external users. Table 3 shows a summary of external sites, where we supported the installation and usage of READEX software components. We took the questions and suggestions of external sites into account and extended the READEX tool suite so that it supports additional hardware and software stacks. We describe our work shortly in Section 3.3. Furthermore, we took questions and hints into account to streamline the installation process of the READEX tool suite and extend our documentation.

Table 3: Collaboration with external sites

External Site	Target Audience
Aker BP	Aker BP were interested in testing out the READEX methodology. However, they have outsourced their HPC systems. We provided them access to the NTNU cluster and supported them with using READEX tools to instrument and tune an elastodynamic wave equation solver program. We describe the latter in Deliverable D5.3.
Barcelona Super Computing Center (BSC)	We have supported the installation of READEX tools on the test system cobi. We also support the installation of READEX on MareNostrum4 and applied READEX to Alya in collaboration with EoCoE and BSC. The evaluation of READEX on Alya will continue on MareNostrum4 as a part of the ICHEC-led PRACE-5IP Task 7.2.
CINECA	We evaluated the READEX methodology using DVFS and hyperthreading on the D.A.V.I.D.E. supercomputer (POWER8 system with EXAMON energy monitoring framework). Furthermore, we implemented a Score-P plugin to connect to the EXAMON power measurement infrastructure. Such a plugin enables D.A.V.I.D.E. users to use the READEX tool suite.
Deutsches Klimarechenzentrum (DKRZ)	We support the installation of READEX software components. We will continue to support them in providing them SLURM extensions developed at TU Dresden.
Edinburgh Parallel Computing Centre (EPCC)	We started collaborating with the EPCC in order to support the installation of READEX on their system.
Höchstleistungsrechenzentrum Stuttgart (HLRS)	We supported the installation of READEX software components on a partition of Top500 the Cray XC40 installation. We furthermore supported the instrumentation and usage of READEX software components for the Open Source CFD flexi[10] resulting in an 11 % energy efficiency gain. We describe the latter in Deliverable D5.3.
Interuniversitair Micro-Elektronica Centrum (IMEC)	We supported the installation of READEX components at IMEC and provided IMEC researchers with access to the READEX project test cluster taurus at TUD, but also to the READEX installation Salomon at IT4I.
Juelich Super Computing Center (JSC)	We supported the installation of READEX software components on a partition of the Top500 system Jureca.
KTH Royal Institute of Technology	We supported the installation of READEX on the KTH Top500 system.
Skoda Auto	We started supporting the installation process of READEX software at SKODA.
Science and Technology Facilities Council (STFC) Hartree Centre	We supported the installation of READEX at the STFC Hartree cluster Neale.

[10] https://www.flexi-project.org/

We also communicated with other sites, which currently do not plan to use READEX. The reasons are manifold. Some lack software interfaces or staff resources, others are currently not interested in energy-efficient computing. Others did not respond to multiple communication attempts. Additional contacted sites include: Lawrence Livermore National Labs (LLNL), Virginia Tech, Oak Ridge National Laboratory (ORNL), Tokyo Institute of Technology, Volkswagen, Michigan State University, and the Beijing Comp. Science Research Center.

3.9 Upcoming and Running Projects that use READEX Technologies

Apart from the projects that use Score-P as base for their research, the project *ProVerB*, funded by the German BMBF will use READEX technology to analyse and optimize the developed code. The project started in April 2018. Furthermore, the software project *lo2s*, which has been supported by the READEX project opens new possibilities for research since it targets a different user group that optimizes for single-node analysis and optimization. The Python instrumentation for Score-P that was developed during the READEX project and which is currently used and tested by external users makes it possible to also optimize Python-based HPC programs for energy efficiency. The *vLive* project plans to use the interfaces we created to implement a live version of the performance analysis tool Vampir. In a further collaboration, NTNU, TUD, and Wireless Trondheim plan to test parts of READEX on embedded ARM processors. In an initial telephone conference call, the partners talked about hardware and software characteristics. NTNU will continue the cooperation project with Aker BP referred to in Section 3.6. Initial experiments with the AkerBP wave equation solver show that its dynamic behaviour and energy efficiency is tightly coupled to its memory access pattern, which can be adapted to the problem scenario for a factor of up to 2.7x improvements on the test system. As this program transformation affects the optimal parameters for energy efficiency, application of the READEX methodology and tools will be a key component in upcoming studies of this effect. The collaboration with BSC on tuning of the Alya application will be continued in PRACE-5IP Task 7.2.

3.10 Exploitation Plans at Partner Level

TUD benefits from the inclusion of detected application phases and dynamism into application performance traces in Score-P. It strengthens the position of Score-P and the Vampir analysis tool that is developed and marketed by the GWT-TUD, the industrial and contract research platform of TUD. Since TUD provides HPC resources to its researchers and to researchers from the state of Saxony, the READEX Tool Suite will be included in user trainings and workshops to motivate its use to achieve more energy-efficient HPC workloads. Furthermore, the new extendible interfaces of Score-P open new research possibilities. Two bachelor theses already used the developed interfaces. According to the current plans, the vLive project at GWT will use the substrate plugin interface, which we created in the READEX project to create a plugin that enables a Live-version of the Vampir performance analysis tool. Finally, TUD will use the new power measurement libraries to analyse newer systems, e.g., AMD Zen processors in other projects, e.g., the DFG SFB HAEC. We furthermore plan to work together with Score-P developers to create new interfaces that extend the capabilities of the Online Access interface used by PTF. After an initial

communication, we found groups at Dresden and Juelich, which would support an extension of the Substrate Plugin Interface.

NTNU has a long history of research on dynamism-aware embedded and cyber-physical systems. The READEX project has significantly broadened NTNU's expertize by producing a large body of knowledge on dynamism in an HPC setting. NTNU sees that there are significant synergies between the work on cyber-physical systems and HPC due to the observed convergence of computing systems, and READEX has helped NTNU attain the necessary expertise and experience to seize this opportunity. This will be exploited in future cooperation both with their existing partners in the embedded and cyber-physical domain, and in future HPC related projects. Furthermore, NTNU hosts and operates key parts of the Norwegian computational infrastructure, including the Vilje supercomputer and its upcoming replacement system, which is expected to enter the Top500 list in a 2019 time frame. These systems support a broad application range of importance to national research efforts and improvements to their energy efficiency promises to benefit Norwegian society greatly.

As a supercomputing centre, **IT4I** frequently organizes workshops and tutorials for both academic and industry users of our supercomputers. The READEX project, its results and potential will be presented on these workshops. Tutorial sessions will be used to teach users how to exploit dynamism in their applications in order to decrease energy consumption of our data centre. As part of the VSB-Technical University of Ostrava, students focused on HPC will receive proper training in developing energy-efficient HPC application using the READEX Tool Suite. In the EXA2CT project, IT4I is developed novel linear solvers for Exascale systems with main focus on performance and extreme scalability. These solvers are key components of many industrial applications. As energy-efficiency is another key factor in reaching Exascale, our participation in the READEX project will provide us with a unique opportunity to identify dynamic behaviour, to develop energy-efficient sparse linear solver algorithms and to evaluate their impact on the respective applications.

ICHEC has used the READEX tool suite, particularly the tools and techniques for dynamism detection to better understand and analyse the commercial and academic codes with which ICHEC deals in its regular operation. As a member of PRACE, ICHEC has also presented and used the READEX approach to other FETHPC projects and CoEs including a project as a part of Task 7.2 in PRACE-5IP. The knowledge and experience gained from dynamism analysis, auto-tuning and Exascale energy-efficiency is being applied and extended in upcoming Irish and EU project proposals in which ICHEC is involved. Furthermore, ICHEC will deploy the READEX tool suite on the new national HPC system that ICHEC commissions in Sep'18 and promoted for use by industrial and academic partners that avail of the national HPC service.

TUM integrated the results of the project into its lectures Advanced Computer Architecture (WS 17/18 and Parallel Program Engineering (SS 18). These lectures are part of the master programs Informatics and Computational Science and Engineering. The lectures introduced the students to the importance of energy efficiency for HPC systems and the relationship between clock frequency and power consumption. In Advanced Computer Architecture, the potential for energy reduction and the most important techniques were introduced. In Parallel Program Engineering, the students used the READEX tools, especially Score-P and Periscope, in exercises and learned about other tools in that area, especially for power capping. TUM will continue this work in future instances of these lectures. Thus, the project already helped to alleviate the shortage in specialized personnel that companies and research institutions face. TUM presented the tools on the tuning workshops of the VI-HPS (Virtual Institute for High-Productivity Supercomputing) (www.vi-hps.org) and plans to continue this effort as it is an excellent chance to train users of large-scale

HPC systems in Europe and worldwide. TUM organized a workshop at the TUM Meeting Center in Raitenhaslach on the future development of PowerStack[11], which was attended by more than 30 people from all over the world. The workshop brought together experts from academia, research laboratories and industry in order to design a holistic and an extensible power management framework. The PowerStack explores hierarchical interfaces for power management at three specific levels: batch job schedulers, job-level runtime systems, node-level managers. The READEX project contributed to the workshop as one of the main tools on energy efficiency tuning.

Intel will exploit the READEX Tool Suite in its joint work with partners in European institutions who are closely associated with the European Exascale Labs: CEA and the HPC centres in France and BSC in Spain, among others. Furthermore Intel has deployed the READEX tool suite on test system at BSC in Spain and explored its potential and capabilities in comparison to GEOPM. GEOPM is an Intel package developed in collaboration with ANL for power policy management of parallel applications. Intel has written a module such that READEX tool suite can be applied on a GEOPM ready application, and further exploration on how these tools can interoperate and complement one another will broaden further the applicability of READEX in a wider range of HPC and datacentre systems. Finally, READEX tools and methodology will be presented to groups within Intel and to the OEM community in order to broaden the community its interest in using READEX for their own activities.

As a commercial partner, **GNS** will benefit from the project in multiple ways. First and foremost, the code optimization techniques and tools developed in the project will enable GNS to improve the performance and the energy-efficiency of its sheet metal forming simulation system OFSolv (formerly known as Indeed), thus leading to a more competitive position on the market. Moreover, the results and methods can also be applied to optimize the company's other software products. This particularly applies to the new *ProVerB* software package that is currently under development within the framework of a German government (BMBF) funded project and that will allow the long term simulation of the behaviour of concrete under mechanical load. In addition, the collaboration with leading research institutes will strengthen GNS's ties to the academic sector. GNS expects that these links will lead to a very direct access to the most up-to-date developments in the algorithm development sector and to the most recent trends in hardware systems, thus allowing the company to incorporate very modern and efficient subroutines into its software and to adapt its software very fast to newly emerging hardware concepts. In this way, existing functionalities can be improved and new ones can be added, again improving the company's position with respect to the other market actors. Furthermore, the participation in the project will increase GNS's visibility in the HPC community which can also lead to more commercial contacts, improved opportunities to recruit new staff members and, in the long run, additional turnover.

[11] https://powerstack.lrr.in.tum.de

4 Summary

In this document, we have laid out our communication activities and our dissemination, collaboration, and exploitation efforts. Furthermore, we describe, how the project partners will use READEX technology in the future.

Part of the dissemination activities are 31 publications, the (co-)organization of five workshops and 20 poster presentations. Furthermore, we communicated over the website, via Twitter, and ResearchGate. READEX technology is installed at eleven European HPC sites. Furthermore, we collaborated with external scientific projects and interest groups, and released 13 software modules at github and on our webpage under liberal licenses (BSD-Clause-3, whenever possible).

5 References

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