

**Business Model with Alternative Scenarios**

**Deliverable D4.1**

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**Lead author:**

*Jakob Lüttgau, DKRZ*

**Other contributing authors:**

*Julian Kunkel, Jakob Lüttgau (DKRZ)*

*Jens Jensen (STFC)*

*Bryan Lawrence (STFC and the University of Reading)*

**Contacts:** [esiwace@dkrz.de](mailto:esiwace@dkrz.de)

**Visit us on:** [www.esiwace.eu](http://www.esiwace.eu/)

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# 1. Abstract /publishable summary

This report summarizes the work on requirements and business models for the storage infrastructure within weather and climate data centres (although much of the work has

wider applicability). The report concentrates on identifying and evaluating the interplay

of important cost factors, along with an introduction to relevant (storage and data movement) hardware and software technology, terminology and performance metrics.

The report begins with a description of how climate and weather applications make use of HPC systems, the arising challenges and data requirements, and some trends that are likely to impact future data centre designs. Related work follows that introduces some cost developments, cost modelling and technological developments. The body of the work is an integrated graph-based approach to modelling costs, resilience and performance for storage systems. Storage models are evaluated in several scenarios each introducing some architectural changes to currently deployed high-performance systems and discusses the cost and performance implications. These discussions are made on a high-level of abstraction as no model is able to predict the non-linear behaviour when scaling out big systems accurately. Conclusions identify the potential benefits that more refined models might offer and outline future work.

# 2. Conclusion & Results

The report looked at the evolution of data centres and various approaches concerned with data access that have been used in scientific contexts. We covered the trends in both climate and weather research as well as the development of storage technologies and, in particular, discussed the performance divergence of compute vs. storage. In this context, we also reviewed cloud technologies that have the potential to change the scientific computing landscape. The report also looked at the data centre perspective and vendor perceptions on the cost developments of disks, NAND and tape.

We described high-level considerations for costs, performance and resilience considerations. A hierarchical graph-based approach is proposed allowing us to specify component and system characteristics and costs and visualize them. This also allows to add or remove complexity and detail as becomes necessary and open the possibility for automation. In the model, we also look at the core components that are usually found in data centres. Starting with the smallest components such as hard drives, that provide little tuning opportunities, the report moves on to discuss how derive the emergent performance and cost of small subsystems like individual compute and I/O nodes as well as of larger subsystems like the network or a parallel file system.

The impact of cloud computing is also considered and some configurations costed and found to be significantly more expensive than on-site systems for typical heavily used weather and climate data centres.

In the evaluation, we provided the characteristics for costs and performance of currently deployed systems. Starting from these systems as baseline, we explored changes to the system and the impact on cost, power consumption and performance applying coarse grained models. The scenarios discussed do not aim to quantify the costs accurately but instead provide a qualitative perspective on the implications of various modifications of the system. In that sense, they serve as blueprints for subsequent scenarios. For example, we discussed reducing the storage budget in favour of compute resources – with the goal of doing so without reduction in scientific productivity, and conclude that this requires more intelligent scheduling and staging mechanisms. Researchers would also likely need to drastically change their applications as well as their workflows.

The report shows that the cost developments for the technologies are an important but unknown factor and that it is therefore advisable to push for more flexible infrastructures to make the integration of new technologies easier. One such technology, NVRAM, might shape future data centres radically, but the cost-benefits of this technology is difficult to quantify as the cost-prognostics of this technology does not exist. Similarly, it is clear that cloud-like services from within data centres will become increasingly important, and will depend on flexible infrastructures. Centralizing some resources such as (pooled) memory, introduces some opportunity, but the benefits are difficult to judge right now as we do not yet have all the relevant data. Not withstanding these caveats, the abstract models shed light on the available design space.

While the high-level models can show certain cases for which a certain technology is useful, they cannot quantify the benefit for individual workloads as the dimension of time and the workload characteristics is abstracted. An approach for more detailed models is showcased: Using discrete event simulation, it is possible to account for the workload behaviour of a system. In particular, we introduced a simulation for hierarchical storage systems that integrate tape libraries and online storage. The case study demonstrates the overhead associated with fine grained models but also shows that it is possible to approximate the observed behaviour in the actual system monitoring. It is then shown that by varying the configuration, we can make forecasts for impacts on the quality of service of an alternative system configuration.

# 3. Project objectives

This deliverable contributes directly and indirectly to the achievement of all the macro-objectives and specific goals indicated in section 1.1 of the Description of the Action:

|  |  |
| --- | --- |
| **Macro-objectives** | **Contribution of this deliverable?** |
| Improve the efficiency and productivity of numerical weather and climate simulation on high-performance computing platforms | Yes |
| Support the end-to-end workflow of global Earth system modelling for weather and climate simulation in high performance computing environments | Yes |
| The European weather and climate science community will drive the governance structure that defines the services to be provided by ESiWACE | No |
| Foster the interaction between industry and the weather and climate community on the exploitation of high-end computing systems, application codes and services. | Yes |
| Increase competitiveness and growth of the European HPC industry | Yes |

|  |  |
| --- | --- |
| **Specific goals in the workplan** | **Contribution of this deliverable?** |
| Provide **services** to the user community that will impact beyond the lifetime of the project. | No |
| Improve **scalability** and shorten the time-to-solution for climate and operational weather forecasts at increased resolution and complexity to be run on future extreme-scale HPC systems. | Yes |
| Foster **usability** of the available tools, software, computing and data handling infrastructures. | Yes |
| Pursue **exploitability** of climate and weather model results. | Yes |
| Establish governance of common software management to avoid unnecessary and redundant development and to deliver the best available solutions to the user community. | No |
| Provide **open access** to research results and **open source** software at international level. | Yes |
| Exploit **synergies** with other relevant activities and projects and also with the global weather and climate community | No |

# 4. Detailed report on the deliverable

The work done covers

1. review and summary of the state of the art and related work;
2. gathering of information of data centre characteristics;
3. development of the high-level models;
4. prototyping example scenarios and evaluating the results;
5. providing a model and simulation of a hierarchical storage system; and
6. documentation in the deliverable.

DKRZ was involved in all activities. STFC was involved in 1, 2, 5, 6.

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# 6. Dissemination and uptake

## 6.1 Dissemination

This formal deliverable is the beginning of dissemination. The project participants expect to further refine and publish further results in the academic literature.

**Peer reviewed articles**

None as yet.

**Publications in preparation OR submitted**

Additional work beyond that listed below is planned.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| In preparation OR submitted? | Title | All authors | Title of the periodical or the series | Is/Will ***open access*** be provided to this publication? |
| In preparation | Understanding Costs of Tape Libraries for Hierarchical Storage Management Systems | Jakob Lüttgau, Julian Kunkel | High Performance Computing, Proceedings | Yes, green open access |

## 6.2 Uptake by the targeted audience

As indicated in the Description of the Action, the audience for this deliverable is*:*

|  |  |
| --- | --- |
| **X** | The general public (PU) |
|  | The project partners, including the Commission services (PP) |
|  | A group specified by the consortium, including the Commission services (RE) |
|  | This reports is confidential, only for members of the consortium, including the Commission services (CO) |

We recognise that the “General Public” will get little out of this work, however, by being in the public domain, we expect that we will be able to discuss the work with a range of other important audiences, including vendors, and the wider weather and climate (and storage) community. It is these last two categories: vendors and those responsible for providing data centres for the weather and climate community who are the true intended audience.

# 7. The delivery is delayed: No

# 8. Changes made and/or difficulties encountered, if any

The original intention had been to make a tool available which encoded the work described in the deliverable. That has not yet been possible, but it will form part of future work. However, the intellectual objectives of the deliverable have been met, and while they have not yet been applied to as many uses cases (including within partners) as anticipated, that too will form part of future work when the necessary input data may be

available.

# 9. Efforts for this deliverable

Person-months spent on this deliverable:

|  |  |  |  |
| --- | --- | --- | --- |
| **Beneficiary** | **Person-months** | **Period covered** | **Names of scientists involved, including third**  **parties (if appropriate)**  **and their gender (f/m)** |
| DKRZ | 8 | M1-18 | Jakob Lüttgau (m), Julian Kunkel (m) |
| ECMWF |  |  |  |
| CNRS-IPSL |  |  |  |
| MPG |  |  |  |
| CERFACS |  |  |  |
| BSC |  |  |  |
| STFC | 3 | M1-18 | Bryan Lawrence (m), Jens Jensen (m), Brian Davies (m) |
| MET O |  |  |  |
| UREAD |  |  | Bryan Lawrence (m) |
| SMHI |  |  |  |
| ICHEC |  |  |  |
| CMCC |  |  |  |
| DWD |  |  |  |
| SEAGATE |  |  |  |
| BULL |  |  |  |
| ALLINEA |  |  |  |
| **Total** | **9** |  |  |

# 10. Sustainability

## 10.1. Lessons learnt: from the experiences of the work to date (positive and negative)

The modelling bears a lot of potential to understand the cost-benefit factors and can serve as a discussion point between vendors and data centres but also between data centres and users. These models need the costs and performance characteristics as input and assume linear dependency between variables to simplify the situation (sometimes too much). But even so, determining the base characteristics such as costs for storage may be non-trivial when procurements cover multiple components (storage + compute part of a supercomputer like for DKRZ). Fine-grained models bear the difficulty to obtain the respective data needed for the simulation. In our case, obtaining the workload traces for tape access is non-trivial but shows that we have to increase the monitoring effort on the sites.

## 10.2 Links built with other deliverables, WPs, and synergies created with other projects

Based on these results, we initiated a collaboration between Argonne National Laboratory and the company Kove to discuss cost-benefit of several storage related architectures.

# 11. Dissemination activities

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of dissemination and communication activities** | **Number** | **Total funding amount** | **Type of audience reached**  **In the context of all dissemination & communication activities**  ('multiple choices' is possible) | **Estimated number of persons reached** |
| Participation to a conference | 1 | 2.500 € | Scientific Community  Vendors | Scientific Community |
| *Poster “Modelling and Simulation of Tape Libraries for Hierarchical Storage Systems” (J. Lüttgau, J. Kunkel) at Supercomputing, 2016.* | | | | |
| **Total funding amount** |  | 2.500 € |  |  |

**Intellectual property rights resulting from this deliverable**

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