TERMS OF REFERENCE

FOR

IMPLEMENTING AND COMMISSIONING OF HIGH RESOLUTION LOCAL AREA NUMERICAL WEATHER PREDICTION SYSTEM AT DHM

CONTRACT NO:

BRCH//DHM/S/CQS-42

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Kathmandu, Nepal

1. Background - the BRCH Project

The objective of the Building Resilience to Climate Hazards (BRCH) project is to enhance government capacity to mitigate climate related hazards by improving accuracy and timeliness of weather and flood forecasts (e.g. quantitative precipitation forecasts) and warnings for climate vulnerable communities, as well as developing Agricultural Management Information System (AMIS) services to help farmers mitigate climate related production risks. The project comprises four components:

A. Institutional strengthening, capacity building and implementation support of DHM;

B. Modernization of observation networks and forecasting;

C. Enhancement of the service delivery system of DHM; and

D. Creation of an agriculture management information system (AMIS).

Numerical Weather Prediction (NWP) is part of Component B “Modernization of Observation Networks and Forecasting” and is referred in sub-component B.3 in the Project Appraisal Document.

Numerical Weather Prediction is a cornerstone of any modern weather forecasting activity. A NWP system is software which includes three main components:

i) *Forecast model*, which predicts 3-dimensional atmospheric state in to the near future by using set of hydro-dynamical equations and physical parameterization schemes;

ii) *Data assimilation system*, which brings together the previous model state and the most recent observations in order to obtain the initial conditions for the model in optimal way; and

iii) *Post-processing package* for providing user friendly weather parameters, which are not direct prognostic variables of the model.

A NWP system provides the prediction of complete 3-dimensional state of the atmosphere and surface processes from a few hours up to several days ahead. Modern hydro-meteorological services and products are directly or indirectly based on the usage of the data from the NWP model. The products and data update typically multiple times a day. The goal of a NWP-activity is to provide detailed, accurate and reliable information for hydrologists and meteorologists on duty to serve any weather-dependent customer and stakeholder.

1. Introduction

This Terms of Reference (ToR) is for a Consult /Consulting firm to further develop the operational Numerical Weather Prediction (NWP) system at the Department of Hydrology and Meteorology (DHM), Ministry of Population and Environment, Government of Nepal (GoN). The Consultancy also involves training of the DHM staff to use the model and apply the NWP for the needs of DHM.

Global NWP systems have developed over the years considerably e.g. in terms of increased lead time of predictability and spatial resolution. For example, the European Centre for Medium Range Weather Forecasting (ECMWF) recently (March 2016) updated the horizontal grid size down to 9 km globally. Despite the developments in global models, such systems can still not fully resolve localized weather phenomena such as convective precipitation, different forms of precipitation, mountain winds, low lying clouds, extremes of temperature etc. A particular need in Nepal, addressed by NWP, is to increase accuracy of the precipitation forecast to increase lead time of flood warnings.

Therefore, use of a very high resolution limited area NWP model, with horizontal grid size of only a few km, jointly used with a global model, is well justified for countries like Nepal having highly varying terrain from mountains to tropical plains.

DHM has already some experience on operation with a Weather Research and Forecasting (WRF) Model. The WRF model is also used by Nepal's neighbouring countries like in India. However, none of these high resolution model setups is fully covering Nepal. Therefore, DHM needs to continue pursuing its own NWP-production. 4

2. Specifications for the Enhanced NWP system to be developed as part of this consultancy

2.1 Present status of the WRF model setup at DHM

As mentioned above, DHM has already some experience in using the Weather Research and Forecasting (WRF) model for operational purposes. The present system has 12x12 km^2 horizontal resolution for the outer (parent) domain, and 4x4 km^2 for the inner domain covering Nepal. The model is run with lead time of max 72 h, and launched in principle 4 times a day. At times, however, the model run takes more than 6 hours, i.e. the next model run start time is passed, due to slow data line speed and inadequate capacity of the presently used server.

The BRCH Project Appraisal Document (PAD) states that it is desirable to continue the model development using the WRF due to existing experience and possible synergies with neighbouring countries.

2.2. Characteristics of the model and its physical environment

The new modelling system should be based on an open-source WRF (preferably EMS version) model, which is a meso-scale NWP-system with non-hydrostatic dynamical core enabling km-scale modelling.

The model needs to include several choices of physical parametrization schemes suitable in both “convection permitting” (grid-size order of 1-3 km) and “synoptic scale” (grid-size 6-9 km or larger) modes. The parametrization schemes should be able to describe processes such as radiation, turbulence, cloud microphysics (multi-phase scheme to be suitable for “convection permitting” mode), convection (deep and shallow), surface and soil processes.

The modelling system has to include double-nesting capabilities enabling both the high-resolution domain covering Nepal and immediate surroundings and the lower resolution “continental” domain covering in the efficient way.

Forecast model code should support the usage of parallel computing by using standard Message Passing Interface (MPI) and Open Multi-Processing (OpenMP) techniques.

2.3 Configuration requirements

The configuration requirements given below are exemplary and can be considered as minimum requirements for the new operational NWP-system. Figure 1 shows an example of double-nested model domain over Nepal and it's neighbouring countries.

The outer domain should be the same or larger as with the current DHM modelling system. The grid-size of the outer domain should be at least 9 km or lower. The outer domain as in Fig. 1 with 9 km grid-size needs 200x300 grid points in horizontal (the same as in the current DHM modelling system). The outer domain model will operate on “synoptic scale”, and therefore, convection parametrization scheme should be used. The larger outer domain will be used for prediction of large scale systems, such as monsoon precipitation travelling from

Indian Ocean.

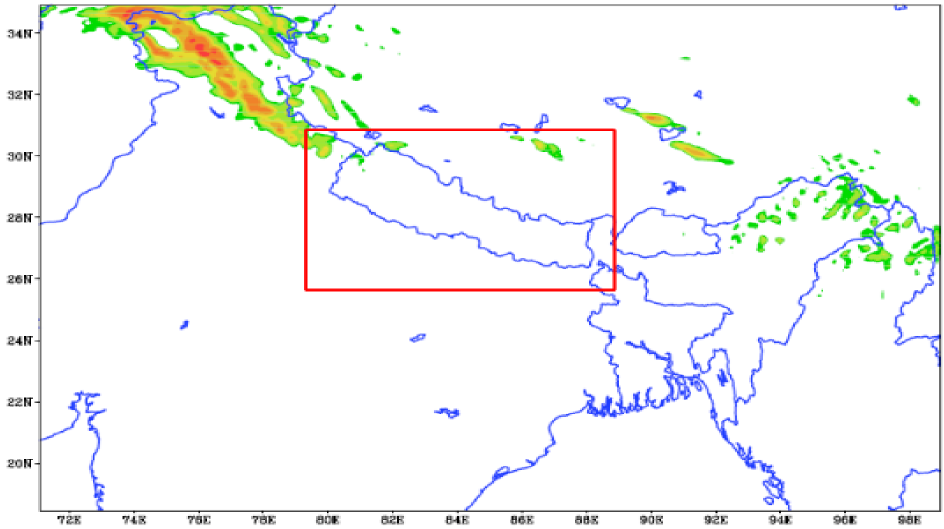

Figure 1: An example of double nested domain stetting for new DHM system. Grid size in outer and inner domains could be 9 and 3 km, respectively.

The inner domain (red rectangle in Fig 1.) should cover the whole of Nepal, and its immediate surroundings. The grid-size of the inner domain should be at least 3 km or finer. The inner model domain will be nested inside the outer domain either with one-way or two-way nesting techniques. The inner domain, as in Fig. 1 with 3 km grid-size, requires approximately 340x200 grid points in horizontal. The inner domain model will operate on "convection permitting" mode, therefore either scale dependent deep convection scheme or "shallow" convection (instead of deep convection parametrization) should be used. The high-resolution inner domain will be used for predicting local scale weather phenomena, such as precipitation, temperature, wind and cloudiness in both populated areas and mountains.

The double nested model system shall produce forecasts at least up to +72h, and be run preferably 4 times per day[1]. The model itself should be backed up with suitable open source scheduling system enabling efficient and automatic triggering of the model run based on time of the day and availability of input data.

1 This depends on the available HPC resource. Initially it is assumed that sufficient HPC-resource exist in order to reach the goal.

One of the key user requirements is the timeliness of the data. Therefore, the model forecast up to +72h should be completed within 2 hours from the start of the model run. The run time for longer lead times (beyond 72h) can exceed 2h.

2.4 Data requirements

The data requirements for the new model system arise from both input and output requirements. The new model system should have built-in capability and tools to use freely available boundary and initial condition data (global data such as provided free of charge by the GFS model system) via internet.

The enhanced system should provide hourly output for at least the basic weather parameters, such as temperature wind speed and direction, total cloudiness, humidity, pressure and accumulated precipitation.

The output data should be given in a standard meteorological file format (e.g. NetCDF or GRIB), which can be handled by the subsequent production chain (e.g. possible databases and/or workstations).

The new modelling system should include post processing package for deriving other weather parameters from the direct model output.

2.5 Visualization and monitoring requirements

The main forecaster tool for viewing and with possibility to manipulate the model data is a called a meteorological workstation. In addition, it is beneficial for model monitoring purposes to have possibility to visualize the direct model output independently (e.g. without unnecessary interpolation steps). Therefore, the new model system should include a built-in visualization tool or the data should be in such standard format, which is understandable for open source visualization tools. In either case, the visualization should be an automated process alongside with model run itself and the products should be available for DHM-staff to view via an internal web page.

Another important monitoring and quality control aspect is verification of forecasts. This document does not take a stand for verification system per se since the verification system will be developed through a separate consulting works. However, the new modelling system should include data processing tools for extracting ASCII-based point forecasts (from freely selected points) for enabling easy use of model data in any verification system.

2.6 Specifications for the data assimilation system

In the second phase of the implementation the new NWP system should include variational data-assimilation (3D-Var and/or 4D-Var) capabilities.

The new model system should include capabilities and tools for handling observation data (from Nepal and neighbouring countries provided by GTS/internet) in both BUFR and ASCII formats. Furthermore, the new system should have capability for generating background and observation error covariance matrices specific for the DHM model domain.

The option of using data-assimilation does pose important monitoring, quality control and visualization requirements. Firstly, the data assimilation package of new modelling system should include observation quality control tools for enabling the data rejection of any suspicious observation. Secondly, the new modelling system should include tools for providing and visualizing the cycle-to-cycle observation usage statistics. This would enable the model operators to monitor the quality and availability of used observations in the data assimilation system.

The enhanced ICT infrastructure and High Power Computing System (HPC, see specifications in Annex I) is being acquired and targeted to be installed prior to this consultancy. The enhanced computing capacity will enable e.g. to widen the inner domain, increase model resolution and implement data assimilation for better initialization of the model by using most recent weather observations. Parallel with this consultancy new automated weather stations (altogether 88 new AWS's will be acquired) will be installed and commissioned to provide real-time data for use in data assimilation and verification of the WRF model. The observation data will reside in a PostGre-type relational database allowing seamless and automated use by the data assimilation.

3. Objectives of the consultancy

The overall objective of this consultancy is to improve DHM's capacity to provide short term weather forecast by establishing an operational high resolution local area NWP system to provide improved guidance for weather forecasting and to help assessment of rapidly developing severe weather situations. A specific use of the high resolution NWP forecast in the BRCH project is to provide quantitative precipitation forecasts (QPF) for flood forecasting and there-by increase lead time for flood warnings.

The specific objectives of the consultancy are:

i) To implement an operational regional NWP system on DHM High Performance

Computing (HPC) platform

ii) To train DHM personnel to develop and maintain the system in their computational platform;

iii) To train DHM personnel to understand the scientific background of WRF-model.

4. Scope of Work

The assignment spans through the development, implementation, testing, commissioning of an operational NWP environment utilizing the newly installed DHM High Performance Computing (HPC) platform and ICT Infrastructure[2]. A vital part of this consultancy is training of DHM personnel to maintain and to further develop of the operational system and to understand the content of the WRF-model, and input and output data.

The functionality of the objective will be cognizant of:

a) Reference to open source WRF NWP-system

b) Ensuring interoperability with other systems in DHM (observation databases, forecast workstations and archives as well as DHM intranet)

c) Building the capacity of DHM selected personnel with appropriate qualification to, optimise and develop system and to understand the operational model structure.

d) Finally the commissioning of this system will aim at increasing usage of NWP forecast data and products at DHM , particularly (but not limited to) regarding the Quantitative Precipitation Forecast (QPF) in order to make better warnings about hydro-meteorological hazards in Nepal.

The scope of the work consists four tasks, briefly summarized as follows:

Task 1 will focus on implementing the operational system first in downscaling mode on the DHM's new computing platform. The implementation includes installation and testing the WRF-model system and auxiliary software, interfacing the input data to the model, interfacing output data to downstream systems and documentation of the new operational environment.

[2] Detailed specification of the DHM's renewed ICT Infrastructure the HPC hardware are presented in Annex I

Task 2 will extend the new operational WRF-system with data assimilation (DA). This includes implementing an operational DA-system, interfacing observation data streams to the DA-system, defining background error statistics specific to DHM model domain, implementing monitoring system for observation usage and documentation of the new DA-system.

Task 3 will focus on training of DHM personnel to use, maintain and further develop the new operational NWP-system. This task includes organising training workshops on both meteorological and technical aspects of the new model system.

Task 4, envisaged to last about 6 months, will focus on system performance monitoring and providing support to DHM to fine tune the model towards optimized performance.

The prerequisites to start this consultancy are as follows:

i. The new DHM's HPC system is installed and ready for operation;
ii. Enhanced network capacity to obtain boundary data from the parent model are available;
iii. Data interfaces to meteorological workstations are defined;
iv. Observation data streams from Nepal and surrounding countries are available as needed in Task 2.

Regarding the last requirement, Task 2 (data assimilation) can be combined with Task 1, if the observation data management infrastructure is in place at the time of the assignment of this consultancy. The exact timing of the consultancy will be determined during contract negotiation.

4.1 Detailed description of Tasks

Task 1: Building up operational NWP system – Phase 1: downscaling mode

Task 1 will focus on implementing the operational system in downscaling mode on the DHM's new computing platform. The details of technical requirements are given in Chapter 2. Task 1 is divided in 4 sub-tasks. Sub-tasks 1.1-1.3 should involve relevant DHM staff for educational purposes.

Task 1.1: Installation and testing the WRF-model system

The purpose of this sub-task is to install the WRF-model system on DHM's new computing platform in double nesting and downscaling mode as described in the model requirements configuration requirements in chapter 2. The model should be automatically scheduled to run 4 times a day. The minimum forecast length will be +72h. Forecast length can be longer based on the need of DHM. However, the model forecast up to +72h should be completed within 2 hours from the start of the model.

Before Task 2, the new modelling system should be running daily in pre-operational phase. Support should be given to DHM during the pre-operational phase in case of the model related problems.

Task 1.2: Interfacing data streams.

The data interfacing task includes both input and output data as described in paragraph 2.4 'Data requirements'. Firstly, the input data in downscaling mode covers boundary and initial condition data extracted from the freely available global forecasting system, such as GFS. The WRF-model should be able to ingest the most recent boundary condition and initial state in appropriate format.

The new modelling system should provide hourly output. The output data should be given in a standard meteorological file format (e.g. NetCDF or GRIB). Furthermore, this task will make sure that the model output can be ingested into the downstream production applications (database, workstation and verification system).

Task 1.3: Installation and testing of auxiliary software

This task will focus on installation of auxiliary software dealing with visualization and monitoring aspects of the operational NWP-model runs. The main forecaster tool for looking and possibly manipulating the model data is meteorological workstation. In addition, it is beneficial for model monitoring purposes to have possibility to visualize the direct model output independently (e.g. without unnecessary interpolation steps). Therefore, the new model system should include visualization tool. The visualization should be automatic process alongside with model run itself. Monitoring products should be made available for DHM-staff via internal web page.

Another important monitoring and quality control aspect is the verification. Setting up verification system is not part of this task. However, the new modelling model system should include data tools for extracting ASCII-based point forecasts (from freely selected points) for enabling the interfacing the model data in the DHM verification system.

Task 1.4: Documentation of the operational NWP-system and environment

This task will focus on documentation of the new NWP-system operational environment. The scientific documentation can refer to existing WRF-documentation and literature. However, the technical and configuration details of the new system should be documented in detail. The main purpose of the documentation is to give DHM staff all the necessary information for maintaining, troubleshooting and further developing the modelling system.

Outputs of the Task 1:

- Automatically running operational NWP-system in downscaling mode
- Forecast data for forecaster and weather and hydrological services,
- Documentation of operational NWP environment.

Task 2: Implementation of data-assimilation as a part of the DHM NWP system – phase 2

Task 2 will focus on further extending the new DHM modelling system to include data assimilation (DA). DA system should have variational data assimilation capabilities, such as 3D-Var and/or 4D-Var) as described above in paragraph 2.6. Task 2 is divided in 4 sub-tasks. The sub-tasks 2.1-2.3 should involve relevant DHM staff for educational purposes.

Task 2.1: Implementing data assimilation.

This task will focus on implementing DA-system as part of the DHM NWP-system as developed in task 1. The new DA system should be based on the available variational DA-methods as available in WRF modelling framework.

One of the critical components of any DA-system is background error statistics. Poorly defined background error statistic may completely hinder the benefits arising from the recent observation information. Therefore, the new background error statistics specific to DHM model domain should be defined.

In Task 2.1 the consult will build the new model suite (parallel to model suite developed in Task 1) with data assimilation capabilities. This new model suite should be run 4 times a day in pre-operational phase. The results of the new suite should be comparing to the downscaled modelling system. Support should be given DHM during the pre-operational phase in case of the model related problems.

Task 2.2: Interfacing observations to data assimilation system

The new DA-system should include capabilities and tools for handling observation data from Nepal and neighbouring countries. Therefore, Task 2.2 is focusing on ingesting observations from DHM observation database to the DA-system. Furthermore, observations from international networks (via GTS/internet) should be ingested as well.

Task 2.3: Implementing observation monitoring system

One key feature of any operational DA-system is monitoring of the observation usage. Task 2.3 will focus on implementing visual monitoring system, which provides cycle-to-cycle information about used and rejected observations and their values (obs and obs-background). The main purpose of the observation monitoring system is to enable DHM staff to monitor the quality and availability of the used observations as a part of the DA-process. Moreover, this system should give immediate warnings to model operator in case of there are problems with observations.

Task 2.4: Documentation of the data assimilation system.

This task will focus on documentation of the new DA-system environment. The scientific documentation can refer to existing WRF-documentation and literature. However, the technical and configuration of the new DA-system should be documented in detail. The main purpose of the documentation is to give DHM staff all the necessary information for maintaining, troubleshooting and further developing (e.g. including new observations) the new DA-system.

Output of Task 2:

- Upgraded operational NWP-system in data assimilation mode,
- Monitoring system for observation usage,
- Documentation of data assimilation as part of the operational NWP environment.

Task 3: Training of DHM personnel to use, maintain and further develop the operational NWP system.

Task 3 focus on training DHM staff to use, to maintain and develop the new operational NWP system. Task 3 will include two training workshops (both lasting minimum of 5 full work days) for relevant DHM personnel:

- The first training workshop will be devoted to the meteorological aspects of the WRF-model and data assimilation configuration. The target group is the users of the NWP forecasts. The topics should cover the modelling methods, observation usage and interpretation of the forecast results including practical exercises/ hands-on training.
- The second training workshop should cover the technical aspects of the DHM modelling and DA-system environment with practical exercises/ hands-on training. The target group is the model operators/developers. The topics should include installation, compilation, and configuration of the modelling system for various purposes. Furthermore, special emphasize should be given to different aspects of the operational environment built in Tasks 1 and 2.
- Associated with the training (before/after the workshops) the consultants should work alongside with the DHM personnel dedicating to operate, monitor, analyze and develop the NWP system.

The consultant shall prepare a detailed training plan including:

- Outline of training topics with list of target measures for the training
- Level of training with definition of the minimum qualification for participants
- Schedule of training sessions

Training material:

The consultant is required to provide all training material in an appropriate electronic format (.doc, .ppt, .xsls, .pdf, etc.) organized as per training topic.

The training presentations shall also be provided as a set of media files (Windows Media Player Compatible) as per topic of training. DHM shall have permission to make copies of the files on an unlimited basis.

Report on training shall include:

- List of participant names, titles, and email address
- Evaluation of training using an inquiry template (to be provided)
- Training material as instructed above

Output of Task 3

- Reports of training workshops
- Copies of training material as instructed
- Summary of training workshop questionnaire and evaluation.

Task 4: Monitoring of Operational Performance and support to DHM

After commissioning the NWP system for full operation, the Consultant will, with participation of the DHM staff, organize and manage operative monitoring of the NWP system over about one year period. Monitoring shall be based on indicators of performance proposed in the planning phase of consultancy. The purpose of monitoring is to find and fix remaining deficiencies in the model system. Indicators of performance should cover (but are not limited) to:

- Verification of forecast with respect to observations using the established verification system, developed as another consultancy work.

- Number of successful/non-successful runs with record of reasons causing problems

- Data availability for data assimilation

- Length of time to complete model run

Consultant will visit DHM at least 3 times during the year to enhance the performance of the models system. The consultant shall also give support and train DHM personnel, on further optimization of the model. During these missions the consultant will also assist DHM personnel to document Standard Operational Procedures on the operation of the model system.

5. Guidance, Supervision and Quality Assurance

Main activities and deliverables including software, designs, output visualizations and setup will be subjected to supervision and quality assurance at various stages. On all matters, the Consultant will work in close consultation with PMU, SI and DHM. The Consultant can get technical support and guidance from SI as and when required during the period of implementation. In addition the Consultant will hold:

- Regular consultation meetings as necessary with the DHM, PMU, and SI
- Kick off meeting

- Progress meetings to present the intermediate and final results after submission of each associated progress report

6. Client's Commitments (Inputs)

Staff of DHM/PMU will facilitate basic administrative support as well as any needed guidance on the use of the ICT infrastructure and the HPC system to the Consultant. DHM will also provide office space, office supplies, office equipment and furniture as well as access to internet and relevant DHM intranet servers.

At the request of the Consultant, DHM should provide the following documents and material.

1. Available information and data related to the setup (HPC-architecture, data sources and interfaces).
2. Related administrative documents to support of activities.
3. Related parts of Project Appraisal Document (PAD), reports of missions and other relevant publications related to this consulting service.
4. Software and data related to the present NWP set-up at DHM.

7. Consultant's Obligation

Consultant is expected to fully complete all the tasks as mentioned in **Scope of Work.** In addition, the Consultant is expected to be fully self-sufficient in terms of travel, transport and accommodation during travels and stay in Nepal. For the benefit of establishing alongside learning and interaction with the DHM staff, the consultant is expected to have at least 70% presence of the effective work time in Nepal.

The Consultant should provide all software code, software documentation and associated scripts as well as all training material. The training lectures must be provided as live video files as well the all presentation material and maintenance guide in appropriate digital form. The Consultant shall execute the work in close consultation with System Integrator (SI) Teams.

In addition, the Consultant is expected to provide professional experts required accomplishing all the tasks specified in **Scope of Work.**

a. A Consultant will be obliged to fully assure DHM, SI and PMU that the renewed operational NWP system setup is functioning well and smoothly complying with the objectives of the ToR.

b. During the operational phase (Task 4), Consultant shall provide support to DHM for 6 months in case of model (software) related problems.

8. General Requirements of the Consultant

8.1 Requirement of the Consultant

a. Should present at least 3 references on implementing operational NWP systems.

b. The model code shall be based on open source WRF-model (EMS version preferably).

c. The Consultant shall furnish a list of users, who purchased similar system/service in last 5 years, they will be used as reference to check the performance of the offered system.

d. Company standing should be at least 5 years.

8.2 Qualification and scope of professional experts

The Consultant should provide minimum two professional experts. All proposed experts must be fluent in both spoken and written English. Nepali language skill would be an advantage, but not required. The consultant firm is permitted to add, delete and/or combine posts in order to put forward the team best qualified to carry out the assignment, but such modifications must be amply justified and approved by DHM.

The requirements of the professional experts for this assignment will include minimum of the following positions:

WRF model expert(s) (totalling 7.5 effective work months)

The designated WRF Expert will be responsible for this specific task. However the work months can be assigned to 1 or more experts covering meteorological and technical aspect of the assignment.

The expert(s) shall:

- Provide plan and design for establishing the operational NWP system
- Develop the automatic operational NWP environment and train the personnel of DHM to use, maintain, develop and operate the system.

- Work together with other experts to build the interfaces for internal and external data sources (observations, boundary conditions) and DMH intranet/workstations for output.
- Conduct regular consultation with concerned staff/expert of DHM and SI’s and PMU with regard to the tasks specified in Scope of work
- Responsible for overall management including quality assurance, and timely delivery of outputs.
- Provide technical training/support to DHM staff in need of operating the operational NWP system and processing forecast data.
- Provide scientific training of methodologies used in WRF model for DHM staff.

Qualifications:

Consultant/Consulting firm must provide CVs of employee(s) showing at minimum their experience as follows:

- Master’s degree in Meteorology for the expert on meteorological aspect of the model. Master's degree in Information Technology or equivalent for the expert on technical aspects of the model. Relevant PhD degree will be an advantage.
- 5 year of experience (more will be an advantage) in planning, designing, establishing and operating of NWP systems.
- Proven experience in successful design, development, and management of at least two (2) similar projects (more will be an advantage).
- Good IT technical and communication skills.

9. Time Schedule and Deliverables

Table 1. Tasks, assignments, work schedule, effective work time and deliverables

Task #	Description of assignment	Time of completion (months from contract signing)	Effective work months	Deliverables
	Inception report	1	0,25	Report finalized and approved

Task #	Description of assignment	Time of completion (months from contract signing)	Effective work months	Deliverables
1.2	Designing operational NWP environment and interfaces	2	0,5	Specifications of the NWP system
3	Preparation of the training plan	2	0,25	Training plan ready
1.1-1.3	Implementation of the NWP -system phase I (onsite work time)	6	1	Model running in downscaling mode. NWP data available for workstations, database and verification.
	1st Intermediate Report	6	0,25	Report finalized and approved
2.1	Definition of background error statistics for the small domain.	8	1	Background error statistics available for experimentation
2.1-2.3	Implementation of NWP-system phase II (onsite work time)	9	1,25	Model running in DA-model. Data available for works stations, database and verification.
3	Organization of 2 training workshops (5+5 days).	11	0,5	Training courses held and material handed to DHM
	2nd Intermediate Report	12	0,25	Report finalized and approved
4	Operational Monitoring & Fixing Found Deficiencies	18	2	Monthly statistics of system performance made available

Task #	Description of assignment	Time of completion (months from contract signing)	Effective work months	Deliverables
4	Hand over automatically running operational NWP system to DHM by ensuring the smooth and efficient functioning services and documentation	18	0,25	Final Report
	Final Report	18	0,25	Report finalized and approved
		Total of effective months:	**7,5**	

10. Reporting

Reporting requirements shall be as follows:

All reports are to be submitted with 3 hard copies along with e-copies

Inception Report (due after 1 month from contract signing)

The report will be based on elaborated discussions with DHM, PMU and SI. The Consultant shall review and verify the content of the tasks and specifications. Specifically, the Consultant shall review the ToR to identify gaps and make specifications of goods and services necessary for filling task and requirement gaps in implementation of operational NWP-system. The Consultant will also elaborate on: (i) work and staffing plans, and (ii) reporting modalities. The report must also clearly specify all risks and issues, which may negatively affect project deadlines and effective execution of project activities (See Task 1-3 of Scope of work)

1st Intermediate Report (due after 6 months from contract signing)

The report will summarize the work done covering Tasks 1.1-1.3, the training plan and other tasks specified in the project plan submitted by the Consultant in the Inception report. The report identifies and justifies possible changes needed to the plan set in the Inception report. Possible changes will be evaluated by DHM, PMU and SI.

2nd Intermediate Report (due after 12 months from contract signing)

The report will summarize tasks 2.1-2.3 and other obligations completed by the Consultant so far, also identifying and justifying possible changes to the plan set in the inception report up till 11 months from the day of contract agreement. Possible changes will be evaluated and accepted or rejected by DHM, PMU and SI. The report shall also include a detailed plan for the last phase on monitoring of the NWP system performance.

Final report (Due after 18 months from contract signing)

The Consultant shall submit Draft Final report after 18 months of contract signing. The report shall consist of results of all tasks and obligations completed by the Consultant. Final report should also summarize the main results and verification scores from both Phase I and II systems including statistics of the operational monitoring (Task 4). It will also include training manual as well as results and evaluation of the training workshops**.**

11. Payment

1) 10 percent on signing of contract as advance against a bank guarantee.
2) 10 percent after submission and approval of Inception Report,
3) 30 percent after approval of task 1 including the documentation of phase I and 1st intermediate report.
4) 30 percent after approval of task 2 including the documentation of phase II and 2nd Intermediate report.
5) 20 percent after acceptance of Final report and after confirming the well-functioning of the system.

12. Duration of service

The time span of the service will be in total 18 months. However, the effective work time is mainly related to onsite duties in tasks 1-4. The time estimates are given in Ch. 9, Table 2 above.

13. Selection procedure and form of contract

The selection procedure is based on consultant qualification (CQS).

ANNEX I

Technical Specification
of
Communication Equipment for ICT Infrastructure (DHM Networks and Offices) and High Power Computing (HPC) System

1. Introduction

This Annex specifies the hardware for the renewed ICT infrastructure and High Power Computing System for the Department of Hydrology and Meteorology, Nepal as part of the BRCH project.

New ICT infrastructure the HPC system will be the foundation for all operational work carried out at DHM. BRCH project includes significant investment in observation equipment, data management and downstream applications. It is essential to design and implement scalable, high-availability ICT-infrastructure to meet all capacity needs for the coming at least for the next 7 years to come.

All servers, storage and high performance cluster (HPC) will be installed at NITC, Singha Durbar data center. It is assumed that NITC will provide only mains power for DHM systems and public IPv4 addresses for DHM services.

2. Specifications for the ICT Infrastructure

Overall goal of this system design is to provide DHM with state-of-the-art ICT infrastructure capable of supporting their mission critical activities and key projects for years to come. In order to provide world-class services to key customers such as civil aviation and agricultural sector, and to further enhance DHM's position as a national focal point of any weather, climate and hydrology related activities, not only the observation systems but also the supporting ICT systems will be designed and built from ground up to provide reliable and high performance service.

Same high quality requirements will be extended to ICT management supporting processes and development of resources. Procurement, installation and implementation of ICT infrastructure in the PPCR/BRCH-project with the help of SI to provide valuable learning experience and knowledge to DHM and so improve DHM's capacity to maintain and develop these systems in the future. In order to guarantee sustainability of the ICT infrastructure and it's capability to provide high quality services, DHM will focus not only on hardware and software but also management, processes and key resources as illustrated in Figure 1.

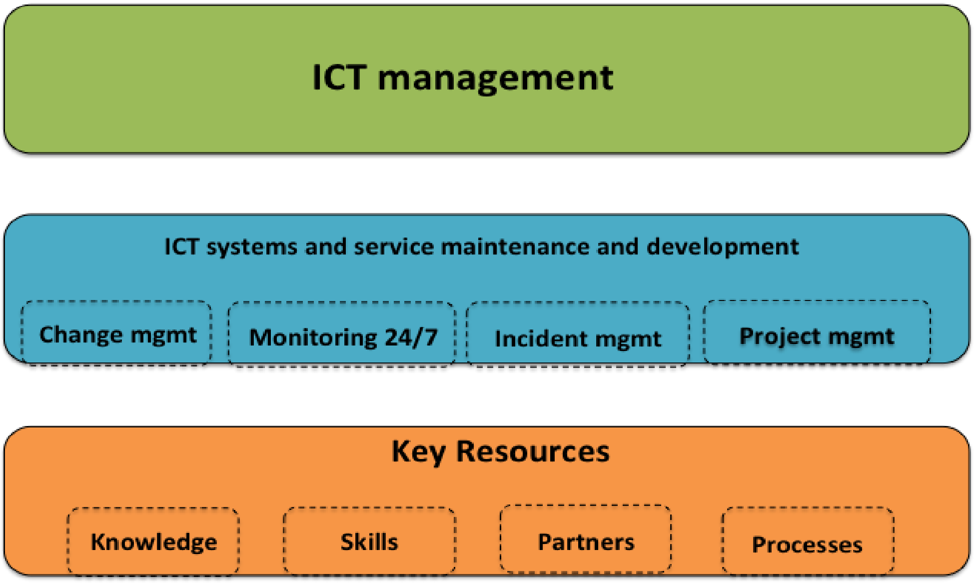

Figure 1. Required focus areas of ICT Infrastructure management

Responsibilities and practices of operational ICT management should be clear and preferably should be duty of a single person reporting to DHM top management. Key processes such as change management, system monitoring 24/7 and incident management should support ICT system and service management. Development practices can be guided with project management practices. Several key resources can be identified that should be developed: knowledge in the broadest sense of the word, skills required, partners as DHM's own resources are limited and processes as described above.

- DHM' s new production system can be described through four functions illustrated in fig1:

- Data retrieval functions including all data flows into DHM's production system such as observation data and GFS weather model data. All these functions will be implemented in the data management system.
- Data warehousing and processing functions that include for example all quality control, data upload to database and file sharing-like data warehouse, data processing such as format conversions and transfer to analytics and R&D functions. All these functions will be implemented in the data management system and further developed by DHM.
- Data analytics and product generation include functions where both hydrological and meteorological value is added to services and products for various customers are generated automatically. All these functions will be implemented in the data management system and further developed by DHM.
- Services and end-users include all distribution methods and channels such as web, FTP, email that are used to distribute services and products to customers. All the function will be implemented and further developed by DHM.

All these four functions will supported by the same shared ICT-infrastructure that is split into three layers: server virtualization, storage system and networking also illustrated in fig 1. The core ICT infrastructure will be installed in the government data center NITC in Singha Durbar, Kathmandu. Networking equipment as required by the design will be installed in DHM's main office and airport office. Outsourcing data center operations will minimize DHM's burden for data center management and cleverly leverages the investment already made for both processes and infrastructure at NITC.

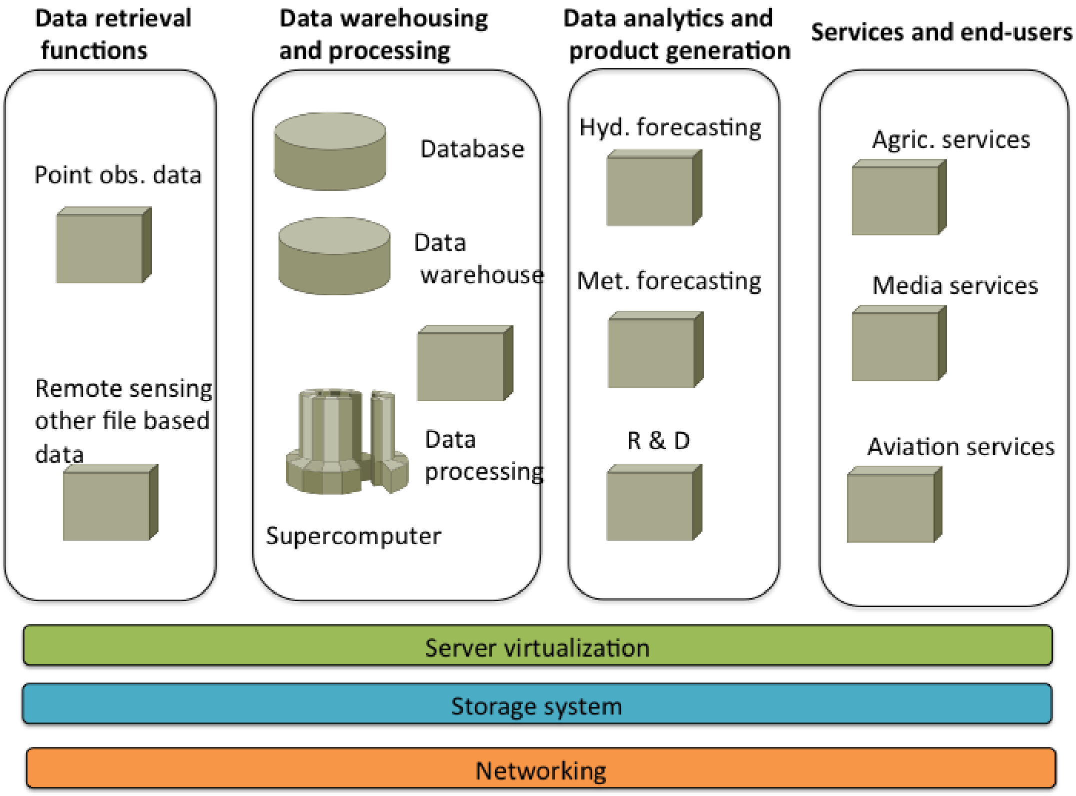

Figure 2. Production system functions and supporting ICT systems

Server virtualization

ICT systems will be based on proven technologies widely used in any modern weather service such as server virtualization, Linux based systems and PostgreSQL database Server virtualization such as VMware, KVM or Hyper-V in high availability-cluster configuration will be used for all processing requirements, web services, data download services, project services etc. Separate physical servers should be installed only when absolutely necessary by the computing requirements of a specific application. Server virtualization will provide not only more efficient use of resources but automatic failover capability and improved reliability.

Storage

The storage system will be a critical component as it will provide services to the server virtualization cluster, guest operating systems such as NFS/CIFS data share, web services and PostgreSQL-cluster. Controllers and other critical components will be duplicated to ensure high availability. Capacity and number of disks have been selected so that the system will meet both capacity and performance requirements in the coming 5-7 yrs. Estimated raw capacity will be 11TB for performance disks and 50TB for capacity disks. High number of spindles is needed not only for capacity but especially to ensure good performance for database and other high activity systems.

Networking

For networking high quality, cost-effective and scalable 1G and 10G Ethernet and other standard technologies will be used. 10G Ethernet has been selected for iSCSI storage-area-network and high speed connectivity for production systems including the HPC cluster. Multi-layer network security will be implemented in the firewalls. All critical systems will be consolidated to government data center NITC in Kathmandu. Data transfers from data center to forecasting department and DHM headquarters require reliable, high bandwidth network equipment and redundant lines. Starting point will be 10Mbps redundant links that can be upgraded to 100Mbps in the future. For field and basin offices establishing suitable telecommunications can be challenging. Services should be designed so that data transfers between data center and remote sites are kept to minimum. In any case a good starting point would be local router with redundant 1-2Mbit/s ADSL-links or single link with some other backup mechanism, even 3G could be considered. For sites with more data requirements a leased line with 1-10Mbit/s bandwidth should be considered. Running costs for leased lines are high, performance unknown and thus not recommended for all field and basin offices.

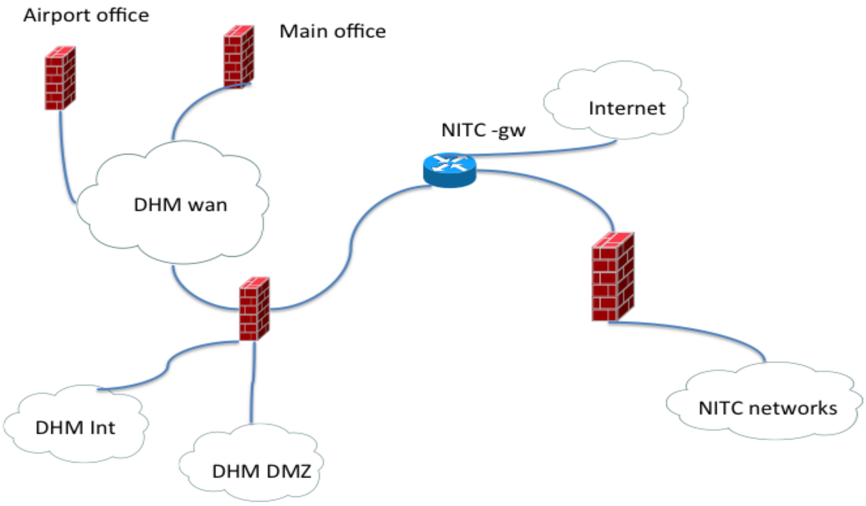

Figure 3 DHM networking

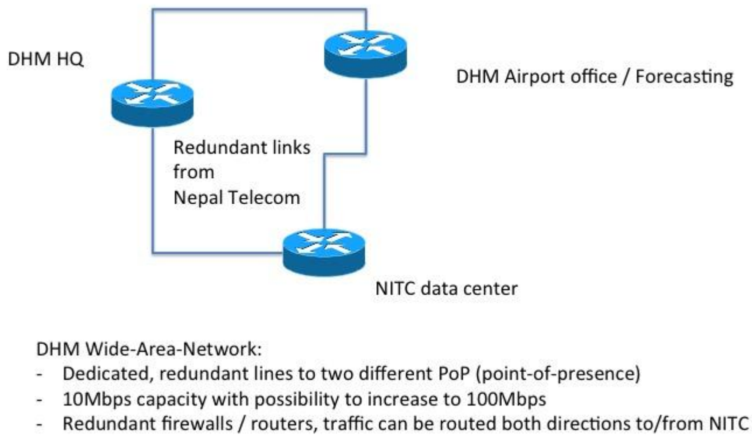

Figure 4. Wide-area-networking

Physical layout

ICT hardware forms a compact system that will install into single rack with appropriate UPS and power distribution systems. The layout has been illustrated in figure 4.

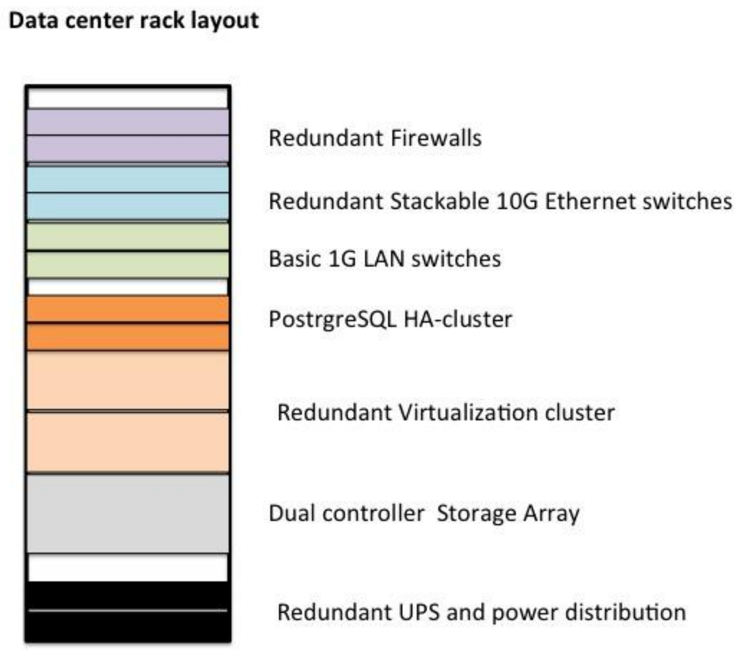

Figure 5. Data Center Rack layout

Data flow volumes

Estimated data flow volumes based on FMI's current operational data flows or extrapolated from current DHM data.

Type	Path	Typical data package size	(Minimum) Transmit interval
Sounding data from 1 sounding station	From stations to database, from database to analysis	Kilobytes	12h

	and production systems		
Met and Hydro observations. By the end of BRCH project DHM will have 94 real-time hydrological stations, 56 manual hydrological stations 100 real-time AWSs, 112 manual climatological stations and 306 manual precipitation stations.	From stations to database, from database to analysis workstations and production systems	All data in the range of kilobytes to hundreds of kilobytes	10min -
Met observations from GTS covering South Asia	From GTS to database, from database to analysis workstations and production systems	1-2 megabytes	30min -
Radar data from 1 radar installed in BRCH.	From radar to data warehouse and further to analysis workstations and production systems	Raw data 100s kilobytes to few megabytes, radar products 100s kilobytes.	10min -
Satellite data	From internet to data warehouse and further to analysis workstations and production	Satellite products 100s kilobytes to few megabytes	Daily
WRF NWP data Double nested, 9km/2km	From supercomputer to data warehouse and further to analysis workstations	NWP output data approx. 16 gigabytes	6h

resolution,72h forecast with 1h output interval	and production	NWP data to workstations 1-2 GB	
GFS data, example data set with various parameters. 120h forecast, 3h time step. 50N,125E; 10S,50E	From internet to data warehouse and further to analysis workstations and production	200MB in 0.5 degree resolution 800MB in 0.25 degree resolution	6h

Cumulative total for 14 day period: approx. 0.9 terabytes. Transmission time for GFS data from with 1Mbps bandwidth is approx. 1h 40min. Transmission time for GFS data from NITC to airport forecasting with 6Mbps (60% of 10Mbps) bandwidth is approx. 17 minutes, 2GB WRF data transmission time 44 minutes respectively.

Data warehousing policy

Mid-term and long-term data policy should keep all observation data and selected remote sensing data online. Current database size is 15GB. Estimated volume for raw data is 0,5GB per year with additional data from value added fields and lightning detection data. Global lightning detection data is 150GB per year. For weather model data, only max. 14 days of data should be kept after which only weather model data required for verification purposes should be kept online. In any case estimated data volumes are very low compared to the 14 day operational requirement.

Future development

Numerical Weather Prediction model data dominate the data flow volumes. Future development will not change the picture dramatically. Main drivers are possible WRF resolution increase to 1,5km that would increase the data from 16GB to 25GB per run. As a longer term (5-10 years) goal ensemble forecasting implementation would increase the data volume dramatically, for example 10 members WRF ensemble would provide 10 times more data. A multi-model PEPS approach is probably more feasible alternative with more useful data processing characteristics and requirements. Possible extension of radar data network could mean installation of five radars all together which would increase the data flow fivefold. Still the cumulative radar data volume is small compared to NWP data. Any optimizations in radar usage, say limiting measurement interval during dry period decreases data volumes.

Infrastructure renewal and associated investment should be planned well beforehand. ICT equipment lifecycle is estimated as follows:

- Network equipment 7-10 yrs
- Storage systems 5-7 yrs
- Servers 5-7 yrs

In the coming 5-10yrs time improvements in energy supply and data connectivity may allow for transformation towards more cloud based technologies, which provide enhanced flexibility and cost-efficiency in ICT infrastructure management.

3. Components to be procured for the ICT infrastructure

The following hardware and software components will be procured:

- 2 x servers for enterprise class virtualization to be installed in NITC
- 1 x server for virtualization management to be installed in NITC
- 2 x servers for Postgres-cluster to be installed in NITC
- 1 x storage system that will be used for all servers to be installed in NITC
- 4 x 1G Ethernet switches that will be used for generic connectivity, 2 installed in NITC, 1 installed in airport office and 1 in main office.
- 2 x 10G Ethernet switches that will be used for connectivity for servers and with iSCSI to the storage system, installed in NITC
- 3 x Firewalls/routers with redundant units that will be used for connectivity between DHM head office, NITC data center and DHM airport office. One device with redundant unit will be installed at each site.
- 1 x 42U standard rack with power distribution units and cable organizers installed in NITC
- 2 x 2.2KVA UPS installed in rack in NITC

- 2 x 1.5 KVA UPS installed in main office and airport office to protect network equipment
- 2 x hypervisors and virtualization management software for enterprise virtualization
- 3 x Linux server operating system for Postgres-servers and management server, CentOS or other free OS version preferred.

All hardware components will include full vendor on-site support for replacement devices and parts and access to new firmware releases on NBD (Next business day) basis. Examples of such support schemes are: HP CarePack, Dell ProSupport. A support scheme based on bidder resources only will not be accepted.

In order to ensure full compatibility, the 10G and 1G Ethernet switches will come from the same vendor.

All proposals will include detailed information or vendor documentation that clearly states that the proposed configuration meets the requirements. Any missing documentation or missing part of the configuration will deem the proposal not valid.

ICT-infrastructure implementation work and systems support will be procured in another tender.

4. Delivery and completion

The hardware will be delivered, installed into rack and hardware tested within 6 months after the contract has been signed. Mandatory hardware tests will include the following:

For **Network devices:**

- will be booted up,
- management interface functionality verified with "shconfig" or similar
- hardware configuration verified via management CLI
- self test launched with visual check on all LED's

Servers

- Will be booted up
- Management connection set up

- Hardware configuration verified from BIOS

Storage

- Will follow vendor's instructions on installation process and system tests
- Present LUN to single Linux server via iSCSI
- Verify both read and write operations with umount/mount to verify that data is actually written to the file system.

5. Specifications for Communication Equipment for ICT Infrastructure and Management System

5.1 Virtualization servers

Processors	2 sockets, 2 CPUS, minimum 10 cores per CPU, 2,5GHz, Intel E5-2600v3 **or similar**
RAM	256GB DDR4with ECC minimum
Chassis	Rack-mountable, 2U with at least 4 PCIe slots
Power supply	Redundant, hot-swappable, 230AC 50Hz
Local disk	Local Raid1 controller with 2x146GB SAS (or bigger), hot-swappable disks DVD-ROM, internal or external
Network connectivity	4x1GbE iSCSI HBA: 1x Dual port 10GbE with SFP+
Remote management	Full lights-out-management via Ethernet: power cycle, remote console, virtual DVD etc.
Rack mount kit	Rack-mount kit included
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice.

4.2 Postgres-database servers

Processors	2 sockets, minimum 8core CPU per CPU, 2,4GHz, Intel E5-2600v3 **or similar**
RAM	32GB DDR4 ECC minimum
Chassis	Rack-mountable 2U with at least 4 PCIe slots
Power supply	Redundant, hot-swappable, 230AC, 50Hz
Local disk	Local Raid1 controller with 2x300GB SAS (or bigger), hot-swappable disks
Network connectivity	4x1GbE iSCSI HBA: 1xDual port 10GbE with SFP+
Remote management	Full lights-out-management via Ethernet: power cycle, remote console, virtual DVD etc.
Rack mount kit	Rack-mount kit included
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice.

4.3 Management server

Processors	2 sockets, minimum 8core CPU per CPU, 2,4GHz, Intel E5-2600v3 **or similar**
RAM	64GB DDR4 RAM with ECC minimum
Chassis	Rack-mountable 1U or 2U
Power supply	Redundant, hot-swappable, 230AC, 50Hz
Local disk	Local Raid1 controller with 2x300GB SAS (or

	bigger), hot-swappable disks
Network connectivity	4x1GbE iSCSI HBA: 1xDual port 10GbE with SFP+
Remote management	Full lights-out-management via Ethernet: power cycle, remote console, virtual DVD etc.
Rack mount kit	Rack-mount kit included
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice.

5. Network equipment

5.1 10G Ethernet switches

Management	Remote management via SSHv2 command-line interface (CLI), SNMPv1-3, NTP
Rack-mountable	Rack-mount kit included
Power supplies	Redundant, hot-swappable, 230AC, 50Hz
Connectivity	24 x 10GbE ports, SFP+, stacking with 10Gbps minimum, 12 pcs SFP+ devices included per switch.
Advanced features	Stackable, several switches can be managed as one, multi-switch/chassis link-aggregation (HP IRF, MC-LAG or similar).
L2 features	Standard spanning-tree support: STP, RSTP, MSTP, STP Root Guard Link-aggregation IEEE 802.3ad

L3 features	IPv4: VRRP, static routing, policy routing, OSPFv3, full support for IPv6
Security	ACLs, IP source guard, Port isolation
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice.

5.2 1G Ethernet switches

Management	Remote management via SSHv2 command-line interface (CLI), SNMPv1-3, NTP
Rack-mountable	Rack-mount kit included
Power supplies	Redundant, hot-swappable, 230AC, 50Hz
Connectivity	24 x 1GbE ports, 2 x 10GbE ports with SFP+, 2 pcs SFP+ devices included per switch.
L2 features	Standard spanning-tree support: STP, RSTP, MSTP, STP Root Guard Link-aggregation IEEE 802.3ad
Security	ACLs, IP source guard, Port isolation
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice.

Both the 10G and the 1G Ethernet switches will come from same vendor.

5.3 Firewalls

Management	Advanced GUI, Command line interface (CLI) via SSH2 for L3 features, configuration rollback
Connectivity	Minimum 4x1GbE SFP +interfaces, 4 SFP+ devices included per firewall. Minimum 12x1GbE
L3 features	IPv4 and IPv6: VRRP, static routing, OSPFv3, DNAT, SNAT, site-to-site VPN tunneling
Security	Stateful firewall with clustering to HA unit.
Advanced security	Cloud based anti-virus, application security, anti-spam, web filtering
High availability	Redundant unit with automatic failover and failback, active-passive and active-active configuration support, session mirroring between devices
Stateful firewall inspection throughput	Minimum 1.8Gbps
IPS throughput	Minimum 230Mbps
VPN throughput	Minimum300Mbps
Concurrent sessions	Minimum 200k
Licenses	Full 5 year licensing for all above mentioned features.
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware releases. Suitable spare part set for local maintenance as per vendor best practice..

5.4 Storage system

Controllers	Two controllers in redundant mode, mirrored cache between controllers, cache persistency provided by battery or other technology. Minimum 16GB cache. Failure of single controller will have no affect on system or client operations. Connectivity: at least 2x10GbE for iSCSI, support for link-aggregation and multi-chassis link-aggregation. All SFP+ devices included that are needed for redundant data path connectivity.
Features	Raid levels: RAID1, RAID5, RAID6 Thin provisioning
Virtualization	Support for virtualization technologies such as Vmware, Hyper-V, RHEV, Xen
Operating system support	RedHat Linux, SuSE Linux, Ubuntu Linux, MS Windows Server
Multipath	Support for native Linux dm-multipath
Power supply	Redundant, hot-swappable power supplies 230V 50Hz
Data path redundancy	Redundant data paths from storage shelves to controllers, from controller to controller and to possible IO units.
Management	System management GUI
Disk capacity	24x600GB 15k SAS, 24x3TB NL 7,2kSAS, should include hot-spare configuration as per vendor best-practice
Licenses	Full 5 year licensing for all above mentioned features.
Vendor hardware support	Full NBD on-site hardware support for 5 years covering spare parts and access to firmware

	releases. Suitable spare part set for local maintenance as per vendor best practice.

5.5 Rack, power distribution units, uninterruptible power supplies, cabling and SFPs

Standard data center rack	Enterprise quality 42U rack, external width 600mm, 19" wide enclosure, cable organizers
4 x Power distribution units (PDUs)for rack	Enterprise quality PDUs, vertically mountable within 42U rack, input 230V 16A 50Hz, output 230V 16A 50Hz, single phase, 1 x input IEC-320 C20 -type connector, 10 x outputIEC-320 C13-type connector, max 10A per outlet,
2 x 3KVA Uninterruptible power supply (UPS)	Enterprise quality UPSs, rack mountable, 2U size, management via USB, input 230V 50Hz, output 230V 50Hz sine wave, 1x IEC-320-C20 input connector, 6 x output IEC-320-C13 connectors, >90% AC-AC efficiency in online mode, maintenance free battery with intelligent battery management, automatic and manual bypass capability, surge protection, overload capability, input circuit breaker, minimum 4 minutes battery capacity at full load
2 x 1KVA Uninterruptible power supply (UPS)	Enterprise quality UPSs, tower model, management via USB, input 230V 50Hz, output 230V 50Hz sine wave, 1x IEC-320-C20 input connector, 6 x output IEC-320-C13 connectors, >90% AC-AC efficiency in online mode, maintenance free battery with intelligent battery management, automatic and manual bypass capability, surge protection, overload capability, input circuit breaker, minimum 4 minutes battery capacity at full load
Stack cable pair for 10G switches	Redundant cabling with SFP+
20 x Cat6 RJ-45 cables for connecting servers, storage and network equipment	Suitable length for single rack installation

management interfaces	
10 x multimode optic cables with SFP+ for iSCSI connectivity	Suitable length for single rack installation,
All power cords	Suitable length for single rack installation, compatible with PDUs.

5.6 Virtualization software; hypervisors

Enterprise grade virtualization	Vsphere, RHEV, Hyper-V or similar
Management suite	Advanced management suite: vCenter, SC operations manager or similar
High availability	Two or more hypervisors can be configured in a HA-cluster
Live migration	Guest operating systems can be migrated from one hypervisor to another transparently
Live VM snapshots	Guest operating system snapshots that can be used for example to rollback from operating system update.
Physical resource pooling : “Resource Pool” or similar	Resource pools are used to manage physical hardware resources
VM template	Creating templates of virtual machines that share same configuration, network settings, applications
VM clone	Cloning virtual machine from template so that the settings are inherited from the original
Virtual network / bridging	Support for virtual network interfaces, bridging, virtual LANs
Linux guests supported licensed	Full support for Linux operating system as guest.

Windows guests supported and licensed	Full support for Windows server operating system as guest.
Software subscription for 5 years	Full basic subscription for all features above will be included.

6. HPC cluster configuration

Item	Qty	Configuration
Cluster node (minimum 512 cores in all for compute nodes)	23-32	2 x Intel Broadwell 2695v4 CPU with 18 cores minimum 2GHz or similar 128GB RAM DDR4 FDR Infiniband HCA 1G Ethernet IPMI management Redundant power supply 480GB local disk for scratch
Frontend node	2	2 x Intel Broadwell 2640v4 minimum 2GHz or similar 128GB RAM DDR4 FDR Infiniband HCA 10GEthernet for user access and data transfers from/to cluster storage IPMI remote management SAS RAID1 RedHat Enterprise Linux 6.5 or similar Cluster management suite (see below for details)
Storage, possible to integrate with Frontend node	1	SATA/SAS minimum 7200RPM system with hardware RAID6, total 32TB useable disk space, expandable to 64TB, NFS share to cluster nodes, FDR Infiniband HCA, 10G Ethernet for user access
FDR Infiniband switch	1	FDR Infiniband switch 1U form factor, 36 QSFP+ ports, redundant power supply, Mellannox FDR Infiniband cables
Ethernet switch	1	48-port 1G Ethernet switch for cluster management and IPMI connectivity, Ethernet cables

Item	Qty	Configuration
Cabinet with power distribution units	1	Standard 19 inch 42U rack with 230V/50Hz power distribution units Vertically mountable within 42U rack, input 230V 16A 50Hz, output 230V 16A 50Hz, single phase, 1 x input IEC-320 C20 -type connector, 10 x output IEC-320 C13-type connector, max 10A per outlet, All power cords.
Monitor and keyboard for administrator access	1	Flat screen monitor, US keyboard
Uninterruptible power supply 3KVA for storage and frontend node	1	Enterprise quality UPSs, rack mountable, 2U size, management via USB, input 230V 50Hz, output 230V 50Hz sine wave, 1x IEC-320-C20 input connector, 6 x output IEC-320-C13 connectors, >90% AC-AC efficiency in online mode, maintenance free battery with intelligent battery management, automatic and manual bypass capability, surge protection, overload capability, input circuit breaker, minimum 4 minutes battery capacity at full load
Spare parts	1	Suitable spare part set for quick local maintenance as per vendor best practice.
Cluster resource management and administration software pack with monitoring capabilities	1	Full Linux cluster management suite for cluster management, administration such as OS image deployment, software deployment, and software upgrades. Monitoring of hardware and software components with Graphical User Interface (GUI) and possibility to send notifications with email.
HPC software pack with scientific libraries	1	• Full Linux HPC software pack with: • MPI libraries for FDR infiniband with compatibility features below. • GNU-compilers for C,C++ and Fortran, • Python 2.x and 3.x • R • Java • Libraries: HDF5, NetCDF3 and NetCDF4 • Math libraries: GOTOBlas, ScaLapack, GMP, FFTW Environment modules interface to switch compiler and library environments.

Item	Qty	Configuration
Batch system	1	Basic scheduling system to launch jobs from frontend to cluster nodes. Open source system such as SLURM preferred.