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## Deliverable D5.1 Interim report about international collaborations and recommendation for large scale quantum communication infrastructure development processes, policies and standards

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### Abstract

The main objective of WP5 International cooperation, preparation for the large-scale European QCI deployment to strengthen and contribute to the further development of the existing EuroQCI collaborations and help extend it with new international partners. We report our continuous collaborations with the neighbouring EU countries. We had meetings and mutual visits to exchange the experience gained throughout the project and contribute to the development of the overall EuroQCI architecture and long-term policy objectives, relevant policies and strategies, and synergies with activities at European and national level. We also report our active engagement in the EuroQCI



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KIFÜ on behalf of the QCIHungary project. The research leading to these results has received funding from the European Union's Digital Europe Programme under Grant Agreement No. 101081247 (QCIHungary).

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CSA Petrus. In this report we will summarise the progress and achievements of the QCIHungary during M1-M12 of the project (01 January 2023 - 31 December 2023).



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## Executive Summary

This report summarises the work we carried out in international collaborations and development of recommendations for large scale quantum communication infrastructure development processes, policies, and standards. In section 1 we list the national and international collaborations where we presented our projects and discussed the various approaches to build national networks. In the next section we highlight the international quantum communication events where we presented our development work. In section 3 we summarise information gathering we conducted with QKD vendors, and research about standard interfaces of upcoming QKD devices. We found that standardisation had not been addressed yet with the large-scale deployment of QKD devices. In the section 4 we present the activities related to the work with Petrus CSA. Finally, we conclude, that we should continue more intensively the collaboration.

## 1 Collaboration with various national and international partners and potential quantum communication infrastructure providers

### 1.1 National events to initiate collaboration on quantum communication

Representatives of the consortium presented the QCIHungary project at some national events to initiate collaboration. We list the events in chronological order.

#### 1.1.1 Workshop 2023 Conference

Between 12-14 April 2023, for 32nd time the Hungarian higher education and research and public collections organised one of the most prestigious Hungarian computer network and application IT conferences, called Workshop. This year, the host of the event was Pannon University in Veszprém. The conference coincided with the "Veszprém-Balaton 2023 European Capital of Culture" programme, giving the event special significance. Workshop conferences regularly attract around 350-400 professionals from research and education from Hungary. János Mohácsi, Head of international R&D at KIFÜ, coordinator of the QCIHungary project presented in the conference about the Challenges of the Quantum ERA and possible answers proposed by the QCIHungary project [NWS2023\_JM].



## QCIHungary projekt javaslat

A QCI Hungary pályázat fő célja egy **leendő magyar QKD kommunikációs hálózat** alapelemeinek **kiépítése**. A részcélok közé tartozik a **hálózat tesztelése** egy valós **közhasználati** eseten keresztül, a **magyar QKD rendszerek működésének továbbfejlesztése**, szakértők és jövő nemzedékek **képzése és oktatása**, valamint **nemzetközi együttműködés** az EU kvantumkommunikációs ökoszisztémájában való sikeres részvétel érdekében. A pályázat részét képezik a későbbi, **műhold** által közvetített **kvantumkommunikáció** felé megtett lépések valamint a QKD-hálózati kapcsolatos szoftverek fejlesztése.



Figure 1 Workshop 2023 presentation about QCIHungary project

### 1.1.2 World Quantum Day

On the international World Quantum Day (14th April), Hungarian stakeholders organised a Meetup, where about 70 participants listened to exciting lectures of Hungarian scientists and experts about the current challenges of quantum technology (in Hungarian).

The program of the event was:

17:15 Zoltán Zimborás (QHungary, HUN-REN Wigner RCP): Opening – The concept of World Quantum Day series of events

17:20 András Gilyén (Alfréd Rényi Institute of Mathematics): If you had a quantum computer tomorrow, what could you use it for?

17:30 Péter Domokos (Leader of the Quantum Information National Laboratory Hungary, Wigner RCP): Can we trust transmon qubits and quantum error correction?

17:40 Gábor Vattay (ELTE): After the NISQ era: The role of quantum computers in the next generation AI systems

17:50 János Lazányi (PCBDesign Ltd., CEO): What controls quantum computers?

18:00 Péter Makk (BME): New types of qubits in solid state physics

18:10 Tamás Kiss (QCIHungary, HUN-REN Wigner RCP): The present and future of quantum communication

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18:20 Q&A session

19:00 Orsolya Kálmán (QCIHungary, QHungary, HUN-REN Wigner RCP): Closing remarks.



*Figure 2 Group photo at the end of World Quantum Day*

### 1.1.3 Celebration of Hungarian Science

At the invitation of the Deputy Secretary General of the Hungarian Academy of Sciences, QCIHungary team member László Bacsárdi, Associate Professor at the BME Faculty of Electrical Engineering was invited to give a lecture on quantum communication at the Science Celebration+ on 14 November at the Hungarian Academy of Sciences. László Bacsárdi talked about the quantum communication activities of Quantum Information National Laboratory of Hungary and the objectives of the QCIHungary consortium, which is implementing the European quantum communication infrastructure in Hungary. [MTA2023\_LB]

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Figure 3 László Bacsárdi at Celebration of Hungarian Science

#### 1.1.4 Annual quantum communication workshop at the Budapest University of Technology and Economics

On 23th November 2023, the BME Faculty of Electrical Engineering and Informatics organised their annual quantum communication workshop at the Budapest University of Technology and Economics on the occasion of the Celebration of Hungarian Science.

The title of this year's workshop was "Looking for challenges: quantum computing and quantum communication at the BME Faculty of Electrical Engineering and Informatics"

Sándor Imre talked about the Hungarian contribution to the EuroQCI and detailed the activities of the QCIHungary project. Eszter Udvary shared the experiences with the integration of the quantum and classical channels. László Bacsárdi highlighted some of their results at the Mobile Communications and Quantum Technologies Laboratory within the free-space quantum communication.

Following the presentations, academic researchers, representatives of three companies shared their vision on quantum communication with the audience. Andras Nagy (CEO, ATL Zrt.) detailed how the threat of quantum computers can be answered using quantum random number generators and QKD. Emil Babics from Magyar Telekom showed why quantum communication related knowledge was important for a telecommunication company. János Barta (Vodafone Hungary) highlighted the future of quantum communication from a viewpoint of a telco company.

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### 1.1.5 Quantum communication presentation at the Hungarian Neumann Conference

To celebrate the 120th anniversary of von Neumann's birth, the John von Neumann Society has prepared a series of commemorative events in 2023. One of them was a Hungarian Neumann conference on 15 November, jointly organised by the Neumann Társaság and the HUN-REN SZTAKI (HUN-REN Institute for Computer Science and Control).

The "After Neumann, freely" Conference focused on different aspects of future trends. László Bacsárdi (Budapest University of Technology and Economics) was invited to give a talk about quantum computing and quantum communication. In his presentation titled 'Evolving quantum technology: from quantum computers to the quantum internet' he had the opportunity to show the importance quantum technology, provide an overview of the activities of the Quantum Information National Laboratory of Hungary, detail the Hungarian plans of the QCIHungary consortium for EuroQCI as well as discuss some of our results with fibre-based and free-space quantum key distribution at BME Faculty of Electrical Engineering and Informatics.

### 1.1.6 HBONE Workshop 2023

"HBONE Workshop" is an annual meeting organised by KIFÜ. There are usually more than 50 attendees, mostly IT engineers from Hungarian academic institutions and KIFÜ. The workshop takes place at various meeting venues in Hungary as a face-to-face meeting (without online participation); the usual duration is two days. The programme includes 15-60-minute talks, panel discussions, and lightning talks. Topics are primarily technical, directly or indirectly related to NREN and campus IT services and technologies.

In 2023, the HBONE Workshop was held at Balatongyörök from November 15 to 17. There were two talks related to QCIHungary: András Jákó from KIFÜ presented a 30-minute introductory talk about QKD technology, briefly covering the problems QKD can solve, essential characteristics of QKD systems, operation of the BB84 protocol, and QKD architectures. Then, János Mohácsi from KIFÜ also presented the QCIHungary project, including its goals, funding, work packages, etc., in 30 minutes.

The programme of the workshop and presentation slides are available at the website: [HBONEWS\_23]

## 1.2 Collaboration with neighbouring countries

We have organised several video conferences with our partners, mainly discussing the possibilities of interstate connections as a preparation for upcoming CEF projects.

We are in a continuous discussion with our Slovak partner SKQCI (with its leader Djeylan Aktas and Mário Ziman, Institute of Physics of the Slovak Academy of Sciences), Czech partner CZQCI (with its leader Jan Bouda, Masaryk University, Brno and Igor Jex, Czech Technical University in Prague), Austrian partner QCI-CAT (with its leader Hannes Hübel). At the beginning of 2023, we had a meeting with Croatian partners to discuss the potential collaboration in the CEF project. Our main contacts were Saša Davidović (CARNET) and Martin Loncaric (Ruder Boskovic Institute).

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Similarly, we had discussion with Romanian partners about a potential collaboration. Our main contacts were Mihai Carabas and George Pantelimon Popescu (University Politehnica of Bucharest) and Octavian Rusu (RoEduNet). We also contacted the Polish, Greece, and Irish NatQCI projects. We had discussion with them about the possible future collaboration.

Péter Ádám, Orsolya Kálmán and Tamás Kiss ( HUN-REN Wigner RCP) participated at the Central European Workshop on Quantum Optics (CEWQO2023) in Milan (3rd-7th July 2023) where they could discuss the challenges and problems related to the European QKD network with several members of the above-mentioned NATQCI projects.

## 1.3 European and other international collaboration

The members of the consortium participate in various international collaborations.

### 1.3.1 GÉANT collaboration

Many NRENs (National Research and Education Networks – responsible for providing and developing advanced, internationally interoperable networking infrastructure and services for national research and education) started to investigate quantum communication technologies and continued to share their results in GN4-3 project in Deliverable 6.5 Network Technology Evolution Report [GN43\_D65] and Deliverable 6.7 Network Technology Evolution Update [GN43\_D67].

Based on this collaboration several NRENs lead or participate directly in the NatQCIs while others take part indirectly. GÉANT, through the Quantum Strategy Group and the GN5-1 Network Development Work Package (WP6) Quantum technologies subtask, facilitates the information sharing between the NRENs. It is particularly interesting in view of the EuroQCI activities, how to efficiently connect QKD and PQC infrastructures in order to provide complete solutions. Some NRENs participated in activities focused on such issues via the OpenQKD project. The following infrastructure was presented and tested as a proof of concept [RYD-2022]. The European NRENs regularly meet and discuss their QKD activities. Summary of their activities presented the annual TNC 2023 conference in Tirana, Albania [TNC2023\_QT]. János Mohácsi discussed QCI activities with representative of Polish, Greece, Italian, Irish, Croatian and Czech NatQCI projects.



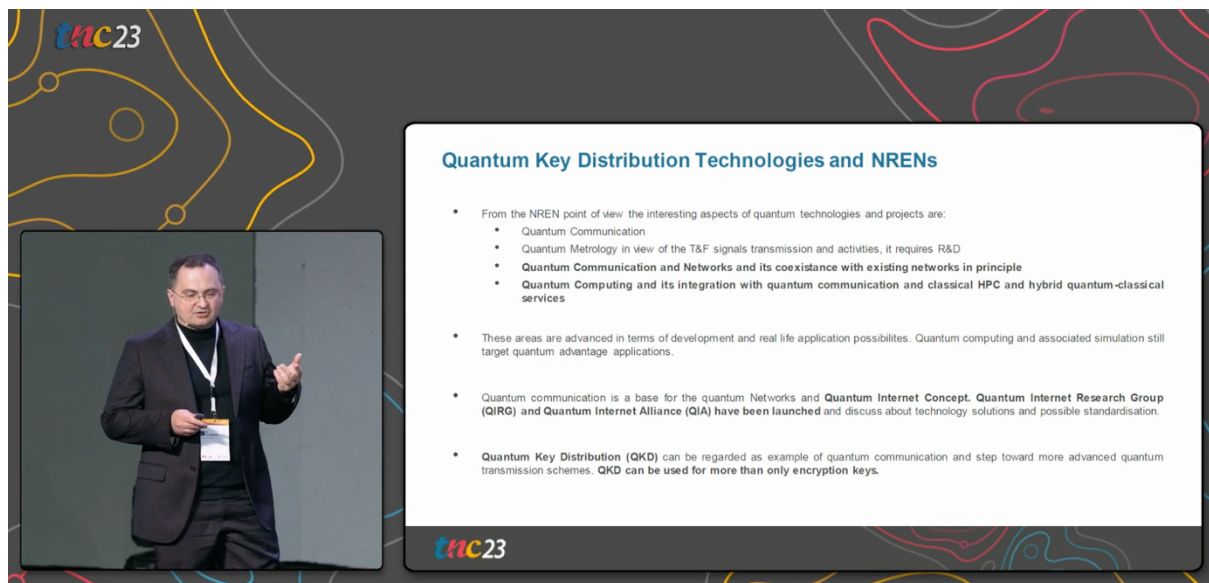


Figure 4 Results of GÉANT quantum collaboration presented at TNC2023

Some examples of the NRENs that participate in the EuroQCI initiative are listed as follows. This list is by no means complete, but reflects on the work of NRENs that are part of the GN5-1 WP6:

- HellasQCI – Greece | GRNET (COO)
- PIONIER-Q – Poland | PSNC (COO)
- CroQCI – Croatia | CARNET (COO)
- BE-QCI - Belgium | BELNET
- IrelandQCI – Ireland | HEANET
- QCIHungary – Hungary | KIFÜ (COO)
- RoNaQCI – Romania | RoEduNet
- CZQCI – Czechia | CESNET
- QCINed – The Netherlands | SURF
- CYQCI – Cyprus | CYNET

### 1.3.2 ESA conference in Netherlands

László Bacsárdi and Márton Czermann (BME) participated in the ESA New Capabilities & Countries in European Space Conference 2023 on May 22-24 in the Netherlands. In their presentation titled “Testing free-space quantum communication” they introduced the goals of the QCIHungary consortium to the audience of the conference. During the conference, they had the opportunity to detail the free-space communication activities to different ESA executives.

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### 1.3.3 5G Techritory Forum in Riga

László Bacsárdi (BME) was invited to give a talk at the 5G Techritory Forum in Riga, Latvia. The event was organised on October 18-19 with the “Embracing the Quantum Era” session on October 19.

In his online talk, Laszlo Bacsardi presented their latest results at the BME Faculty of Electrical Engineering and Informatics in fibre-based quantum key distribution, free-space and satellite-based quantum communication, as well as detailed our plans in the QCIHungary consortium for 2023-2025.

### 1.3.4 Migration to Quantum-Safe Workshop

Orsolya Kálmán (HUN-REN Wigner RCP) participated at the workshop (February 9-10, 2023, Vienna, Austria) organised by ID Quantique Europe. The two-day event featured talks from experts in the field of quantum communication, quantum key distribution, quantum cryptography and several hand-on sessions and demos, where the QKD solutions of ID Quantique were presented.

## 1.4. Activities related to market consultation and standardisation

### 1.4.1. Vendor discussions

In WP2, during the preparation for the QKD and encryptor procurement, we concluded that a preliminary market consultation was needed at the beginning of the public procurement procedure.

We prepared a draft call for tenders by May 2023, then compiled the initial questions for QKD and encryptor manufacturers. Based on previous enquiries and correspondence, we also compiled a list of manufacturers (with contact details) to invite to the market consultations.

Seven vendors accepted the invitation:

- AdvaNet (Hungary, official representative of Adva/Adtran)
- ATL (Hungary)
- ID Quantique (Switzerland)
- KeeQuant (Germany)
- Telsy/QTl (Italy)
- ThinkQuantum (Italy)
- Toshiba (United Kingdom)

Based on the information gathered during the first round of the online market consultations, we amended the technical specifications of the upcoming procurement and had internal discussions in

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the consortium. For those parts of the technical specifications where questions remained, a second round of the market consultation questionnaire was compiled and sent out. This second round was carried out via email , without live meetings. We processed the responses and then revised and further refined the technical specifications of the procurement based on the results of the market consultations. We collected the among following parameters for procurement and standardisation interfaces;

- Size,
- reach of the equipment,
- QKD protocol,
- key rate at certain reach
- KMS and RNG integration,
- power consumption,
- interface for key management,
- Interfaces for monitoring
- possibility of secure node,
- capabilities to demonstration and training

### 1.4.2. Study of relevant standards

The consortium started to collect the relevant standards for QKD. QKD standardisation is crucial to ensure interoperability, reliability, and security of these implemented systems. Standards play a vital role in facilitating The interoperability of QKD systems, enabling their integration into existing infrastructures, establishing proper interfaces between different components, and ensuring compliance with specified requirements regarding performance and security. Thus, QKD standards help to reduce the complexity of implementations and promote a broader adoption of the technology. Some standardisation bodies are actively working in the development of QKD-related standards.

Among these bodies, the European Telecommunications Standards Institute (ETSI) has made significant progress in the development of QKD standards through its Industry Specification Group (ISG) on QKD [ETSI-ISG-QKD]. This group aims to address standardisation issues related to QKD with the active collaboration of key stakeholders from the the scientific, industrial, and commercial sectors. Table 1 summarises the published ETSI standards.

Identification	Title	Description
<a href="#">GS QKD 002</a>	QKD; Use Cases	Application scenarios and description on different identified use cases.

<a href="#">GS QKD 008</a>	QKD; QKD Module Security Specification	Definition of functional security objectives: security requirements, module specification, ports and interfaces, roles, software security, physical security, etc.
<a href="#">GS QKD 005</a>	QKD; Security Proofs	Requirements and evaluation criteria for practical evaluation of QKD systems.
<a href="#">GS QKD 011</a>	QKD; Component characterization: characterising optical components for QKD systems	Specifications and procedures for the characterisation of optical components for use on QKD systems, including examples of specific tests and procedures.
<a href="#">GS QKD 003</a>	QKD; Components and Internal Interfaces	Definition of properties of components and internal interfaces of QKD systems, including quantum physical devices and classical equipment present in most QKD systems.
<a href="#">GR QKD 007</a>	QKD; Vocabulary	Definitions and abbreviations used in relation to QKD and ETSI ISG-QKD documents.
<a href="#">GS QKD 014</a>	QKD; Protocol and data format of REST-based key delivery API	Description of a communication protocol and data format for a QKD network to supply cryptographic keys to an application based on a REST API.
<a href="#">GS QKD 012</a>	QKD; Device and Communication Channel Parameters for QKD Deployment	Description of main communication resources involved in a QKD system and the possible architectures that can be adopted to perform a QKD deployment over an optical network infrastructure.
<a href="#">GS QKD 004</a>	QKD; Application Interface	Specification and description of API between QKD KM and applications., including

		sequence diagrams for different scenarios.
<a href="#">GS QKD 015</a>	QKD; Control Interface for Software Define Networks	Definition of the interface between a SDN-QKD node and a SDN controller, description of the flow of information and the information model.
<a href="#">GS QKD 018</a>	QKD; Orchestration Interface for Software Defined Networks	Definition of the interface between an SDN orchestrator and an SDN controller of a QKD network, description of the information flow and the information model.
<a href="#">GS QKD 016</a>	QKD; Common Criteria Protection Profile - Pair of Prepare and Measure Quantum Key Distribution Modules	Specification of a Protection Profile for the security evaluation of pairs of QKD modules under the Common Criteria.

Table 1 ETSI ISG-QKD published standards

ISO/IEC standardisation subcommittee, responsible for developing standards, technical specifications and reports, best practices, and related documents in the field of information security, cybersecurity and privacy protection has developed a two-part standard targeting the security requirements, test, and evaluation methods for QKD., as summarised in Table 2.

Ref.	Title	Description
<a href="#">ISO/IEC 23837-1</a>	Security requirements, test and evaluation methods for quantum key distribution Part 1: requirements	Identification of security requirements and potential attacks.
<a href="#">ISO/IEC 23837-2</a>	Security requirements, test and evaluation methods for quantum key distribution Part 2: test and evaluation methods	Description of test and evaluation methods in order to validate and fulfil security requirements.

Table 2 QKD relevant ISO/IEC standards

The Internet Engineering Task Force (IETF) Quantum Internet Research Group , has published 2 drafts to the field of quantum communications. visible in Table 3 .

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Ref.	Title	Description
RFC 9340	Architectural Principles for a Quantum Internet	Description of the framework and introduction to basic architectural principles for a quantum internet.
draft-irtf-qirg-quantum-internet-use-cases-19	Application Scenarios for the Quantum Internet	Overview and categorisation of applications expected to be used on the Quantum Internet and description of some general requirements.

*Table 3 IETF and IRTF standards*

Many elements of QKD systems, their interoperable interfaces, KMS and multi domain operation are still under discussion.

Therefore, the consortium decided that we will apply the relevant ETSI standards in the procurement selection for maximal interoperability and we will use the ISO/IEC standards in security analysis work.

## 2 Participate in regular international events

### 1.5. EuroQCI Kick-Off -January 2023

Based on the EU Cybersecurity Strategy aimed to boost Europe's cyber-resilience, the EuroQCI initiative was launched in 2019. The first implementation phase starting in 2023, quantum specialists gathered on 24th January to launch over 30 EuroQCI projects, QCIHungary being one of them.

QCIHungary, just like other national project coordinators, presented its project, compared the approaches and discussed cooperation details.

The QCIHungary project also met PETRUS representatives, among them Keith Elder, the programme coordinator.



Figure 5 KickOff in January 2023 in Brussels

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## 1.6. EuroQCI Meeting on June 7 in Brussels

Our colleagues travelled to Brussels to discuss the future of EuroQCI. The QCIHungary project was represented Balázs Visky (KIFÜ) and László Bacsárdi (BMEs). The day was organised by DG-CNECT and PETRUS.



*Figure 6 Meeting in June 2023 at Brussels*

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### 3 Development of processes and policies with the international partners towards designing and building an overall EuroQCI system architecture

#### 3.1 Participation in the EuroQCI Thematic Working Groups (ETWGs)

In order to facilitate the cooperation among the NatQCI projects and make progress to a fully operational EuroQCI and share today's information and knowledge Petrus CSA project initiated 5 EuroQCI Technical Working Groups (ETWGs).

Working Group	Goal of Working Group	QCIHungary representative
Roadmap	Develop a roadmap for EuroQCI, covering all aspects (People, Process, Provider, Product, Platform) leading to the full deployment of EuroQCI	László Bacsárdi, BME
Interoperability and Standards	Develop approach for interoperability from a cross Member State and from a TerraQCI / SpaceQCI perspective.	János Mohácsi, KIFÜ
QKD Landscape	Provide an overview of the QKD landscape and its relation to other technology globally with a focus on Europe and relevant to EuroQCI. Identify state of the art QKD education, technology, and implementations.	Sándor Imre, BME
Architecture	Define a EuroQCI architecture based on the user requirements.	Péter Ligeti, ELTE
Use Cases	Consolidate all EuroQCI use cases and align on EuroQCI service levels	Tamás Kiss, Wigner FK

Table 4 Table 4 EuroQCI Technical Working groups and their goals

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Each working group was established during October 2023 and the members joined the groups according to their responsibilities.

Group	Role
Expert Group	The Expert Group will consist of max 7 people selected from the Petrus team who are experts in the ETWG topic and will be responsible to draft the initial output from the ETWG. The team will be created by the ETWG Lead.
Core Working Group	The Core Working Group will consist of representatives from all stakeholder groups. The number of participants in the Core Working Group will vary depending on the ETWG requirements and the number of stakeholders willing to participate, but will be approximately 15 people max. The selection will be done in conjunction with Petrus and European Commission.
Reviewing Group	The Reviewing Group will consist of participants from all stakeholders. The number of participants is not restrictive but will be limited to one or two representatives from each of the stakeholders. The selection will be based on all stakeholders who volunteer but are not assigned to a Core Working Group.

*Table 5 ETWG subgroups*

On 7th November 2023 EuroQCI Thematic Working Group's face-to-face meeting took place in Brussels, where members of the Core Working Group met. From QCIHungary no WG member participated, since most of the members of QCIHungary belong to the Review working group. Our expert from HUN-REN Wigner RCP, of the Core Working group gave various quantum related presentations in US conferences and events at the same time, so he could not attend..

## 4 Collaboration with the EuroQCI topic 3 project (co-ordination and support action [CSA] ) and with other EuroQCI projects

QCIHungary, like other national projects, was approached by the PETRUS Coordination and Support Action project and started to cooperate on various activities. . Our consortium participated in the 2 workshops organised by Petrus as described in section 2.

QCIHungary also responded to the surveys run by PETRUS. Our consortium members were actively engaged in the training and Q&A session provided by project. We further shared the knowledge we acquired and used them for our project especially to specify the QKD devices and their operational environment we expected to build during our project.

## 5 Conclusions

In 2023, we worked to reach the main objective of WP5 International cooperation on preparation for the large-scale European QCI deployment to strengthen and contribute to the further development of the existing EuroQCI collaborations and help extend it with new international partners.

In this deliverable we reported our continuous collaborations with the neighbouring EU countries, meetings, and mutual visits to exchange the experiences gained throughout the project and to contribute to the development of the overall EuroQCI architecture and long-term policy objectives. We started investigating relevant policies and strategies, and sought synergies with activities at European and national level. We also described our active engagement in the EuroQCI CSA Petrus.

We can conclude that the QCI systems are currently in exponential development. Therefore, we have to continue the following standardisations, and market developments... We should seek more opportunities to exchange information about working systems and distil best practices which can be used for preparation for the large-scale European QCI deployment. We should also exploit the lessons learnt from collaboration with GÉANT and neighbouring countries in the deployment of our national network.

[

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## Glossary

<b>BME</b>	Budapest University of Technology and Economics
<b>ELTE</b>	Eötvös Loránd University
<b>ETSI</b>	European Telecommunications Standards Institute
<b>GÉANT</b>	Pan European Association of European NRENs, providing services for research and education across Europe
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>IETF</b>	Internet Engineering Task Force
<b>ITU-T</b>	International Telecommunication Union Telecommunication Standardization Sector
<b>KIFÜ</b>	Governmental Agency for IT development
<b>KMS</b>	Key Management System
<b>NREN</b>	National Research and Educational Network, providing services for research and education in the country
<b>QKD</b>	Quantum Key Distribution
<b>Wigner RCP</b>	Wigner Research Center for Physics