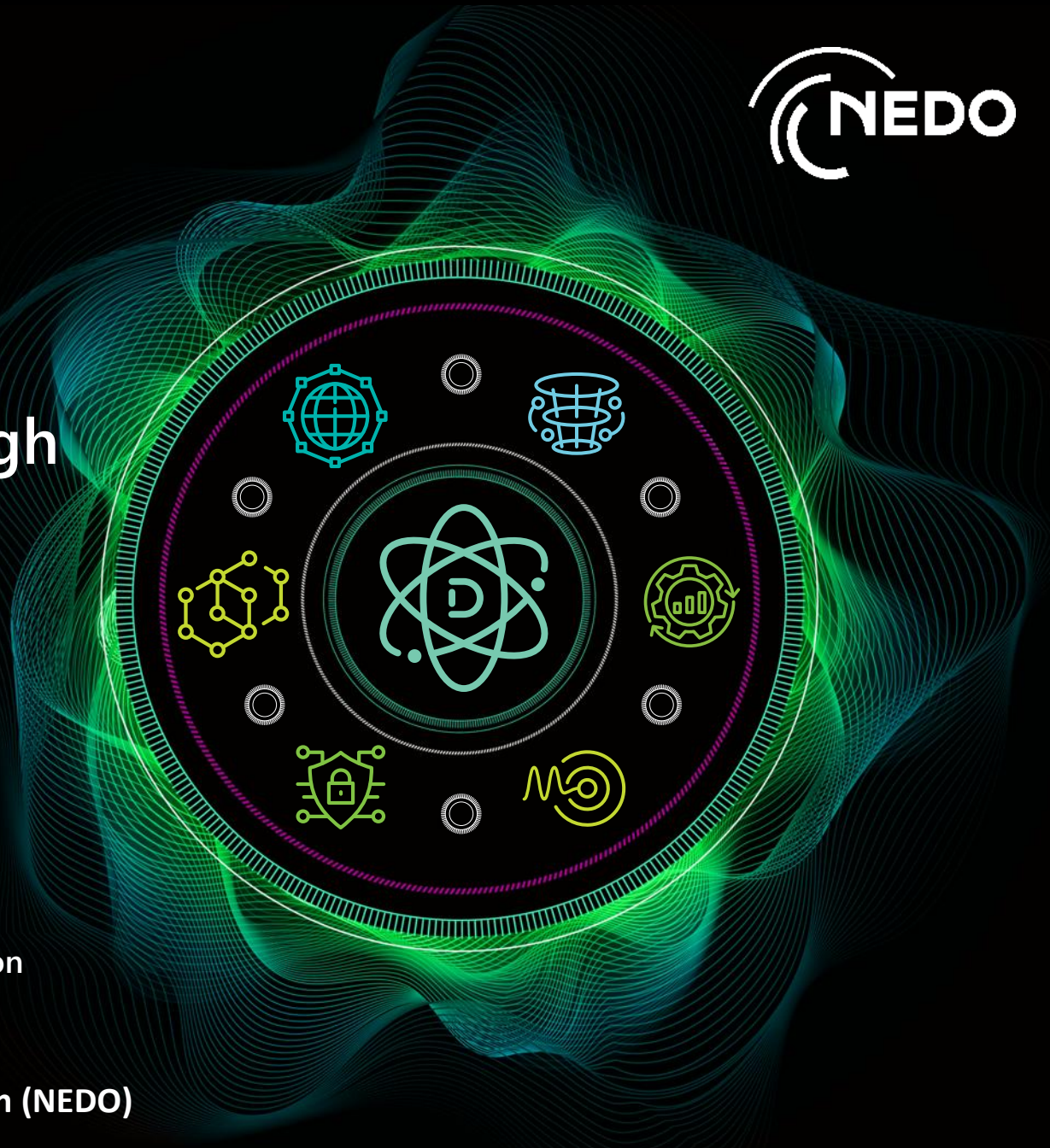
Quantum Computing Use Cases

Early prediction of diseases through the elucidation of biological functions



Promotion of SDGs with Quantum Technology

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New Energy and Industrial Technology Development Organization (NEDO)

生体機能解明による疾患早期予測
Early prediction of diseases through the elucidation of biological functions



ユースケース概要 **Use Case Overview**	生体や薬効の機能解明が進み、身体の不調を補う効果的な治療法を提供 The clarification of the medicinal effects is progressing, providing effective treatment methods.
解決できる課題と効果 **Issues to be addressed and their effects**	健康寿命の延長により労働年数も延長し、2050年には年間約30兆＄の経済効果 Extending healthy life expectancy will also prolong working years and enhance economic effects.
量子技術の貢献 **Contributions of quantum technology**	生体状態を決める分子の相互作用の再現や薬理作用に影響を与える因子の推定 Estimating the influencing factors on pharmacological effects through the reproduction of molecular interactions.

実現予想時期 **Expected realization period**	(Year)2035～2040
産業分類 **Industry classification**	情報・金融・その他サービス Information・Financial・Other services
関連するQRAMI階層 **Related QRAMI layers**	機能層 Functional layer
関連する量子技術 **Related quantum technologies**	量子コンピュータ(FTQC) Quantum Computer(FTQC)

新規性 **Novelty**	一部の新要素 Some new elements
達成難易度 **Difficulty of achievement**	困難 Difficult
社会貢献度 **Social contribution level**	社会全体に貢献 Contributions to society as a whole
市場規模 **Market size**	10兆円～ 10T¥～

Detail

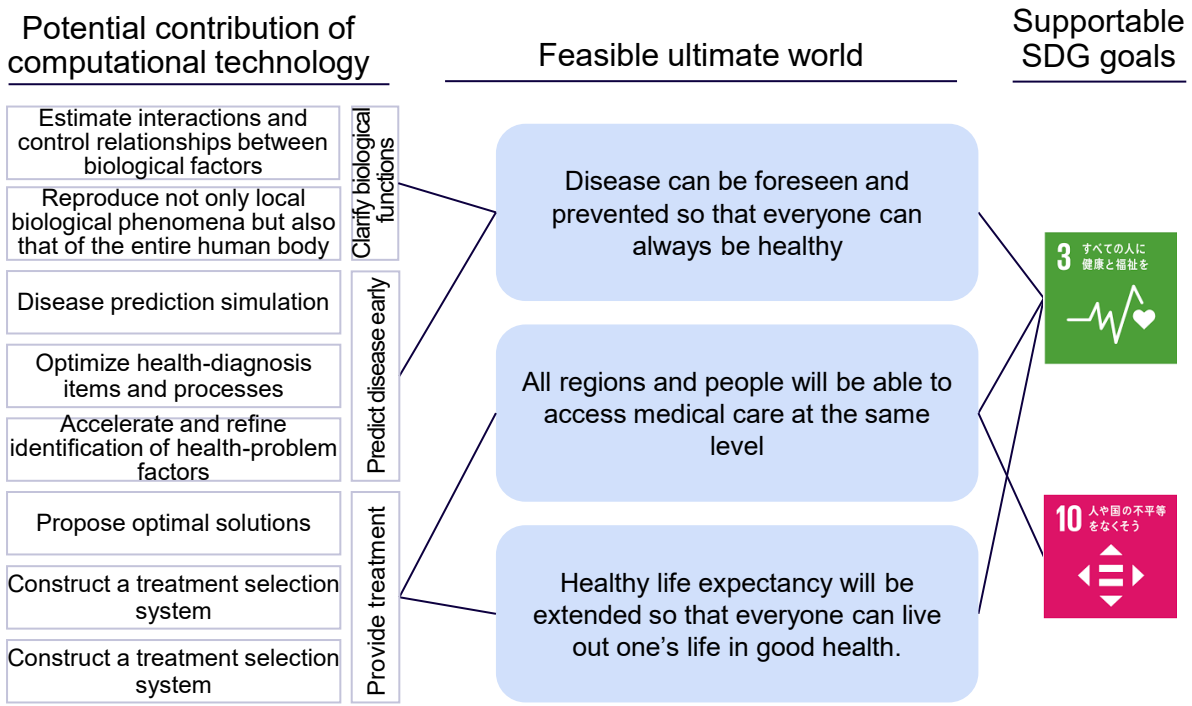
Early prediction of diseases through the elucidation of biological functions

- Everyone will be able to live out one's life in good health as biological and drug-efficacy functions are clarified and effective solutions for counteracting physical disorders become available.



30 trillion dollars
GDP increase

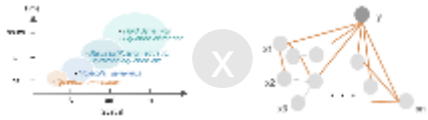
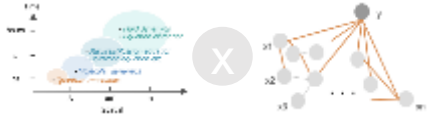
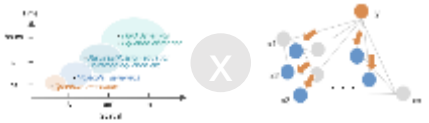
At present, there is a 10-year gap between healthy life expectancy and average lifespan for humans, but use of quantum computers can extend healthy life expectancy so that everyone can live out one's life in good health. This will also extend working years that will have an annual economic effect of about 30 trillion dollars.



Roadmap

Early prediction of diseases through the elucidation of biological functions

Clarification of biological and drug-efficacy functions progresses

Process (1/2)	Necessary R&D and business development	Quantum-computer scope of contribution and future development issues	
Establish biological models	■ Estimate interactions and control relationships between biological factors including quantitative fluctuations in genes and protein, external factors, current biological state, etc. → Precisely reproduce molecular interactions and control relationships that determine biological conditions and formalize as a linear function by combining quantum-chemical and molecular-dynamics calculations. The goal is to reproduce not only local biological phenomena but also more complex, large-scale relationships throughout the entire body (the bottleneck here is that there are parts whose biological roles, interactions, etc. have yet to be explained, e.g., mRNA).	Construct a precise model combining a theoretical model and causal analysis 	■ Accelerate quantum chemical calculations ■ Developing algorithms to solve MD equations quickly ■ Expand the scope of applying quantum computers to statistical analysis including linear regression analysis (develop techniques to expand the application range beyond existing algorithms)
Establish pharmacological effect models	■ Estimate relationships between factors that impact pharmacological effects For example, the following factors are considered to have an impact: age difference, gender difference, animal-species difference, pathological conditions, individual differences (idiosyncrasies, drug allergies, genetic factors, etc.), and psychological effects. →Combining quantum-chemical and molecular-dynamics calculations enables the precise formulation of pharmacological effects at the molecular level	Construct a precise model combining a theoretical model and causal analysis 	■ Accelerate quantum chemical calculations ■ Developing algorithms to solve MD equations quickly ■ Expand the scope of applying quantum computers to statistical analysis including linear regression analysis (develop techniques to expand the application range beyond existing algorithms)
Obtain information	■ Patient information collection system (currently, there is little data on patients who have actually been prescribed medicine) ■ Establish information masking technology to anonymize patient information and enable use of medical data	-	■ None in particular
Disease prediction simulation	■ Establish disease prediction/analysis simulations based on individual genome data and biological/behavioral data. Link to preventive medicine and preemptive medicine (perform preventive treatment since an XX condition makes obesity or diabetes more likely).	Solve union of a theoretical model and causal model 	■ Develop techniques that enable an integrated approach combining theoretical and causal models instead of solving individual models separately

Roadmap

Early prediction of diseases through the elucidation of biological functions

Effective solutions for counteracting physical disorders become available

Process (2/2)	Necessary R&D and business development	Quantum-computer scope of contribution and future development issues	
Establish highly accurate diagnosis technology **(develop a methodology for existing means of diagnosis)**	■ Optimize items/processes in diagnosing health (mechanism for optimizing what examination to perform given symptoms like “my stomach hurts” or “I’m just not feeling well”) ■ Establish sensing technology for accurately grasping state of health (highly precise sensors, wearable or implantable devices that can collect data over the long term, etc.) ■ Identify problem-related factors in health data	Construct a causal model and use it to identify cause (inverse problem) 	■ Expand the scope of applying quantum computers to statistical analysis including linear regression analysis (develop techniques to expand the application range beyond existing algorithms) ■ Accelerate optimal-solution searching and expand base (develop techniques to expand the application range beyond existing algorithms)
Establish a methodology for determining solutions to problems **(develop a methodology for existing means of treatment)**	■ Provide a more optimal solution (group) by combining biological models and pharmacological effect models ➢ Personalized medicine (automatic drug synthesis and clinical trial equipment, surgical robots, etc.) ➢ Non-medical treatments (highly nutritious and functional food, psychotherapy, behavior modification, etc.) ➢ Body/brain augmentation technology (to enable unhindered living even if some bodily functions have weakened) ■ Establish techniques for simulating effects of solutions and construct a selection system based on patient’s preference	Solve inverse problem 	■ Accelerate optimal-solution searching and expand base (develop techniques to expand the application range beyond existing algorithms)
Establish technology for providing solutions	■ Design optimal processes/operations including scalability and cost-effectiveness of various technical solutions	-	■ None in particular
Set up an infrastructure in which every individual can access the above means of diagnosis and treatment	■ Establish a method for accessing quantum computers from many edges ➢ Develop and provide a solution package from daily diagnosis to treatment	Solve many inverse problems 	■ Perform real-time, mass execution of established mathematical models

Roadmap

Early prediction of diseases through the elucidation of biological functions

Clarification of biological and drug-efficacy functions progresses

Process (1/2)

Establish biological models

- Verify the feasibility and business potential of identifying model functions
- Advance research into human biological reactions. Clarify interactions that are currently unclear.
- Accelerate quantum chemical calculations
- Develop algorithms to solve molecular dynamics equations at high speed
- Expand the scope of applying quantum computers to statistical analysis including linear regression analysis
- Construct a model representing a biological state using quantum chemical calculations

Establish pharmacological effect models

- Verify the feasibility and business potential of identifying model functions
- Accelerate quantum chemical calculations
- Develop algorithms to solve molecular dynamics equations at high speed
- Expand the scope of applying quantum computers to statistical analysis including linear regression analysis
- Construct a model representing dynamics and biological reactions using quantum chemical calculations
- Improve preciseness of model predictability while comparing with results of actual clinical trials

Obtain information

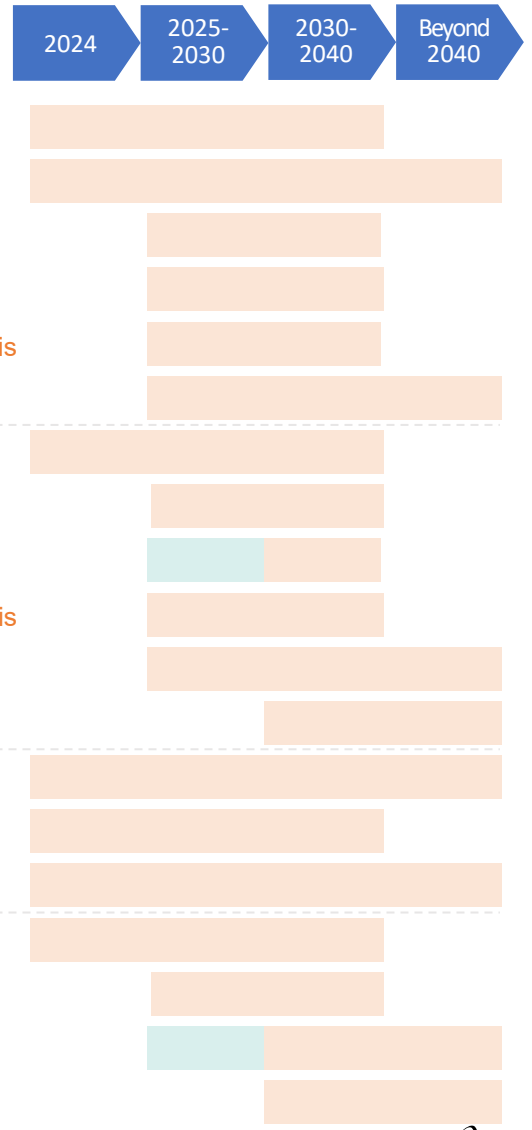
- Collect biological/pathophysiological information using healthcare big data, etc.
- Establish information masking technology to anonymize patient information and enable use of healthcare data
- Construct a platform for sharing data between researchers and healthcare institutions

Disease prediction simulation

- Verify the feasibility and business potential of accelerating calculations using quantum computers
- Develop techniques that enable an integrated approach combining theoretical and causal models
- Develop solutions combining disease prediction algorithm and quantum computing
- Apply solutions toward preventive medicine and preemptive medicine

Necessary steps

Items related to quantum computers



Roadmap

Early prediction of diseases through the elucidation of biological functions

Process (2/2)

Effective solutions for counteracting physical disorders become available

- Establish highly accurate diagnosis technology
- Establish a methodology for determining solutions to problems
- Establish technology for providing solutions
- Set up an infrastructure in which every individual can access the above means of diagnosis and treatment

Necessary steps

Items related to quantum computers

Necessary steps	2024	2025-2030	2030-2040	Beyond 2040
■ Expand the scope of applying quantum computers to statistical analysis including linear regression analysis				
■ Accelerate optimal-solution searching and expand base				
■ Develop optimization algorithms for health-diagnosis items and processes				
■ Establish sensing technology for accurately grasping state of health (including quantum sensors, etc.)				
■ Develop healthcare solutions technologies (personalized medicine, psychotherapy, body/brain augmentation technologies, etc.)				
■ Accelerate optimal-solution searching and expand base				
■ Establish optimal treatment proposals by combining above pharmacological-effects prediction model and quantum computing				
■ Design optimal processes for diverse technical solutions				
■ Perform real-time, mass execution of established mathematical models				

More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

New Energy and Industrial Technology Development Organization (NEDO)
AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the “Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers ”.