Can Quantum Computers Help Build A Sustainable Future?

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**Zero hunger**

Lack of nutrition in infants hamper brain development that is irreversible.

### Table 1. Percentage and number of people affected by severe food insecurity in 2016

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage (±)</th>
<th>Millions (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>9.3 (± 0.4)</td>
<td>688.5 (± 27.6)</td>
</tr>
<tr>
<td>Africa</td>
<td>27.4 (± 0.7)</td>
<td>333.2 (± 8.6)</td>
</tr>
<tr>
<td>Asia</td>
<td>7.0 (± 0.6)</td>
<td>309.9 (± 26)</td>
</tr>
<tr>
<td>Latin America</td>
<td>6.4 (± 0.3)</td>
<td>38.3 (± 2.0)</td>
</tr>
<tr>
<td>Northern America and Europe</td>
<td>1.2 (± 0.1)</td>
<td>13.0 (± 1.3)</td>
</tr>
</tbody>
</table>

*Source: www.worldhunger.org*
In 2015, the UN general assembly adopted the 2030 agenda (Envision 2030) for sustainable development. There are 17 SDGs in total. Some of them are:

**Good health and well being**

We are in the middle of an epidemic crisis, where more than ever we realize the importance of faster drug discovery!

- Enormous social and economic impact.

*Source: pbs.org*
United Nations Sustainable Development Goals (SDGs)

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**Affordable and clean energy**

![U.S. electricity generation by fuel, all sectors](source: walkthroughindia.com)

*Source: US energy information administration*
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**Climate action**

Aftermath of *Cyclone Amphan* from last week. (Left: Kolkata airport after the storm).

- Estimated **13 bn USD** in damages.

Hurricane Harvey (2017)

- Estimated **125 bn USD** in damages.
In 2015, the UN general assembly adopted the 2030 agenda (Envision 2030) for sustainable development. There are 17 SDGs in total. Some of them are:

- Zero hunger
- Good health and well being
- Affordable and clean energy
- Climate action

There are computational problems in each of these areas where quantum computers can have a significant impact.
What is a quantum computer?

Classical computers manipulate bits of 0s and 1s.

A quantum computer manipulates quantum states, consisting of superpositions of qubit states, for e.g. \( |\psi\rangle = \alpha|0\rangle + \beta|1\rangle \).

**Known limits of quantum computation:**

While it is known that a quantum computer can efficiently solve any problem that a classical computer can solve, it is not known whether there exists a problem that can be efficiently solved on a quantum computer but not on a classical computer.

It is also not known if there is any NP-Complete problem that a quantum computer can efficiently solve.
What experts believe?

**Quoting Michael H. Freedman**

“I have a lot of confidence on general grounds that quantum computers will be very powerful, very important; but I can't say exactly what they will be good for. The reason I believe in their ultimate strength is because of the philosophy of how they use information. They process information using QM amplitudes, and probabilities are sort of the ghosts of amplitudes after they have been degraded to our mere classical world. The quantum world is the elegant, precise, unitary world, and the classical world we live in is the corrupt shadow of it.”
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Quoting Scott Aaronson

“The “killer app” for quantum computers will most likely be simulating quantum physics.”
Quantum simulation problems: Hunger mitigation / Agriculture

The best application of a quantum computer is to simulate quantum phenomena, such as molecules, chemical reactions etc.

**Nitrogen fixing fertilizers**

- Around 100 metric tonnes of fertilizers are produced each year.
- The Haber-Bosch process uses around 1.5-2% of global energy.

There are bacteria in nature that can perform the same chemical reaction, and understanding how they do it requires one to be able to simulate the enzymes and proteins forming such bacteria.
Quantum simulation problems: Healthcare / Climate Action

**Drug discovery**
A similar problem exists in the drug discovery process – also requires one to be able to model chemical reactions, and understand how drugs interact with proteins and enzymes in our body.

**CO₂ capture and catalyst design**
Quantum simulations can help in the design of better catalysts that can speed up chemical reactions. Having the capability to do that will allow design of *new catalysts for carbon capture*:
- Currently known catalysts involve precious and rare metals (difficult to deploy on scale)
- No known cheap catalysts currently to do this.
Quantum simulation problems: Clean Energy

**High Temperature Superconductors**

- Transmission infrastructure with zero transmission losses.
- Can also help build better superconducting quantum computers.

**Better Batteries**

- Increased storage and efficiency.
- Will greatly facilitate transition to renewable energy, especially from intermittent sources like *wind and solar*. 
Error Corrected Quantum Computers

All the applications listed here will require large scale error-corrected quantum computers with *hundreds of thousands to million qubits*, which can be anywhere between 10-20 years (or more!) away.

Only way to reduce the development time is to invest in developing this technology right now.
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Current quantum computers can only simulate molecules with a few atoms.

Some of my recent work has been focused on finding quantum error-correction codes that might be useful once we have the capability to build large scale quantum computers.
Theorem: A surface code on a genus $g$ manifold with $M$ odd degree vertices encodes $K$ logical qubits given by

$$K = \left\{ \begin{array}{cl} 2g & , \text{orientable} \\ g & , \text{non-orientable} \end{array} \right\} + \left\{ \begin{array}{cl} 0 & , \text{checkerboardable} \\ (M - 2)/2 & , \text{not checkerboardable} \end{array} \right\}$$

Here $g$ is the orientable / non-orientable genus of the manifold $M$. 
Thank you

For questions contact me at rsarkar@stanford.edu