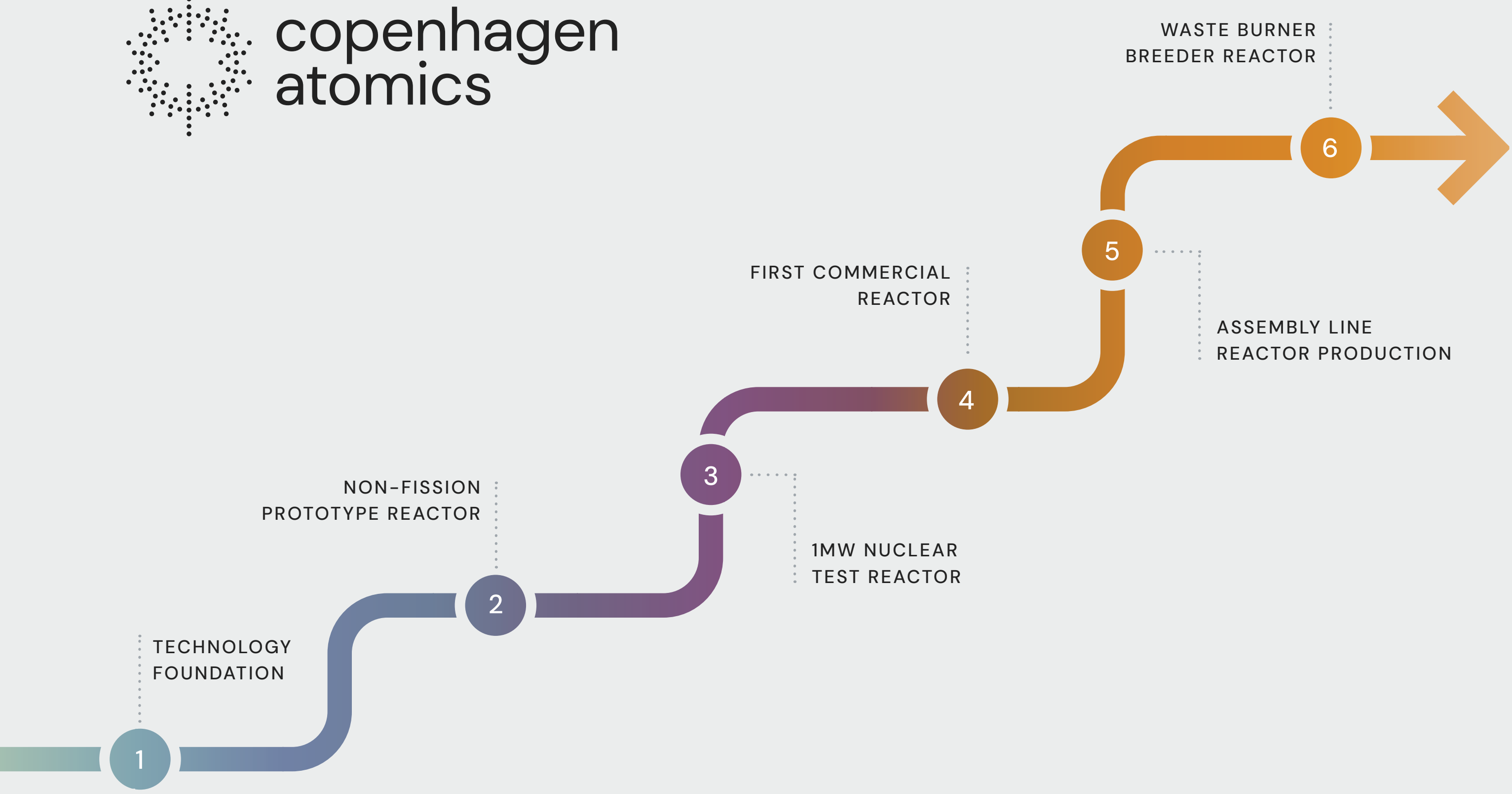

Company roadmap

A document targeting investors.

Version 1.6
August, 2024

copenhagen atomics

About

This document is targeted at investors who wish to understand the journey from inception until the breeder reactor is operating.

This is a non-technical document with a high level introduction to the 6 milestones being developed over two decades and at the end Copenhagen Atomics lists the 6 short term goals that are the focus for the teams right now.

Version 1.6
August, 2024

Executive summary

Figure 1. Roof cutaway visualization of a 1 GW electric plant. 25 reactors + 5 empty cocoons.

Copenhagen Atomics presents a new reactor design, with different physics than all other previous reactor designs, resulting in much lower energy price and less materials used.

Because of the profound difference between Copenhagen Atomics reactors and all other reactors, Copenhagen Atomics also introduces a new business model: Copenhagen Atomics will finance, build, own and operate the reactors on the customer site. The resulting energy prices are expected to be 1/4 of the typical price from classic nuclear reactors.

In addition to radically lower energy prices, this new type of reactor can also use "waste" from classic nuclear reactors, extracting ten times more energy out of this spent nuclear fuel than what the initial reactor was able to extract. Additionally, the waste left behind by the Copenhagen Atomics reactor only needs to be stored for 300 years above ground, vs. 100,000 years of deep geological storage for nuclear waste from traditional reactors. Copenhagen Atomics already has agreements in place about waste handling.

The reactor type invented by Copenhagen Atomics is a thorium molten salt breeder reactor, which fits inside a custom built 40 foot shipping container and can be mass manufactured on assembly lines with an expected output of minimum 1 reactor per day (per assembly line). The target customers are large plants producing commodities such as aluminum, ammonia or hydrogen.

Details about budgets, technical details, R&D plan and commercial strategy are described elsewhere under NDA.

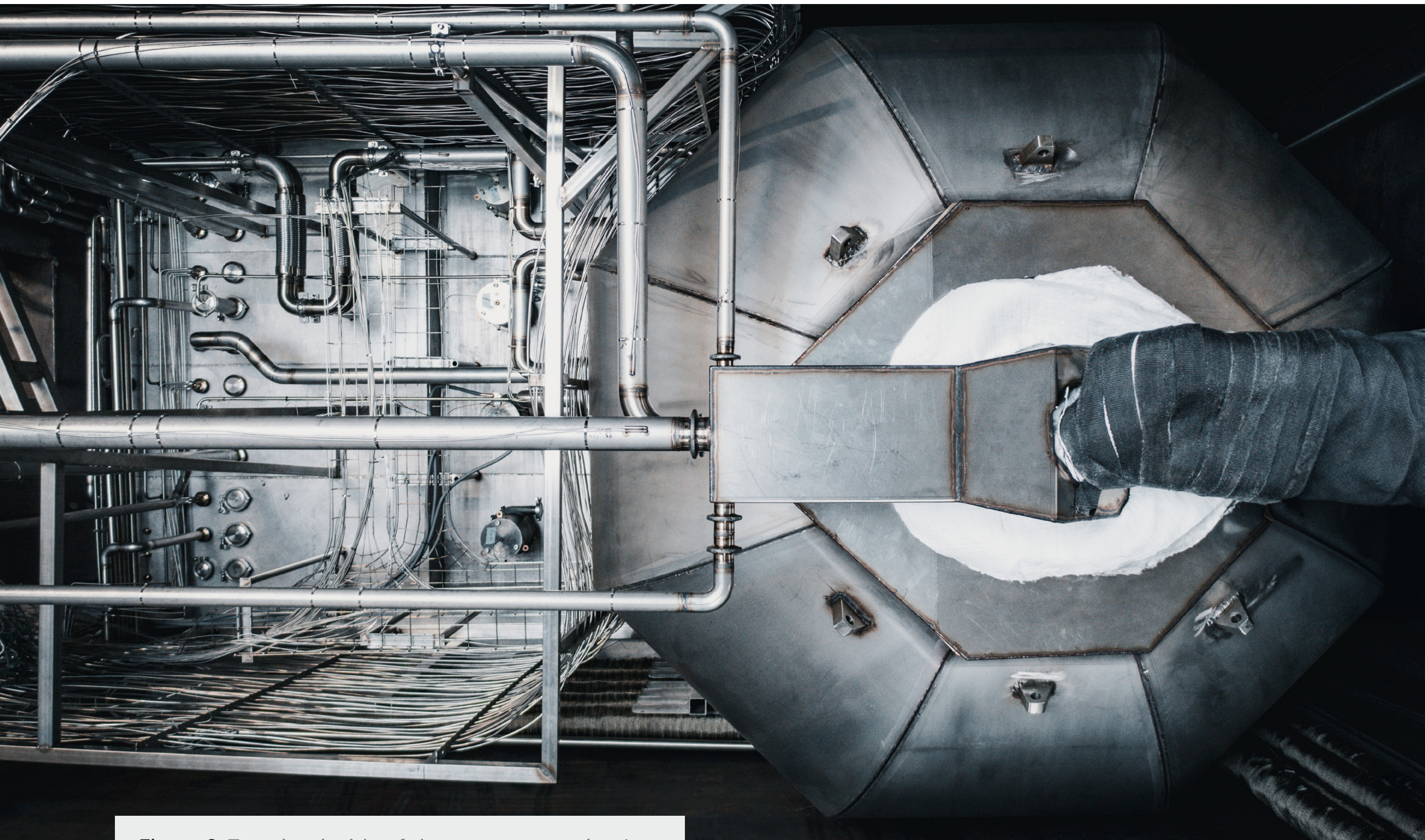

Figure 2. Top view inside of the reactor container's hot side. Onion Core™ can be seen on the right side.

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1. Six milestones development plan

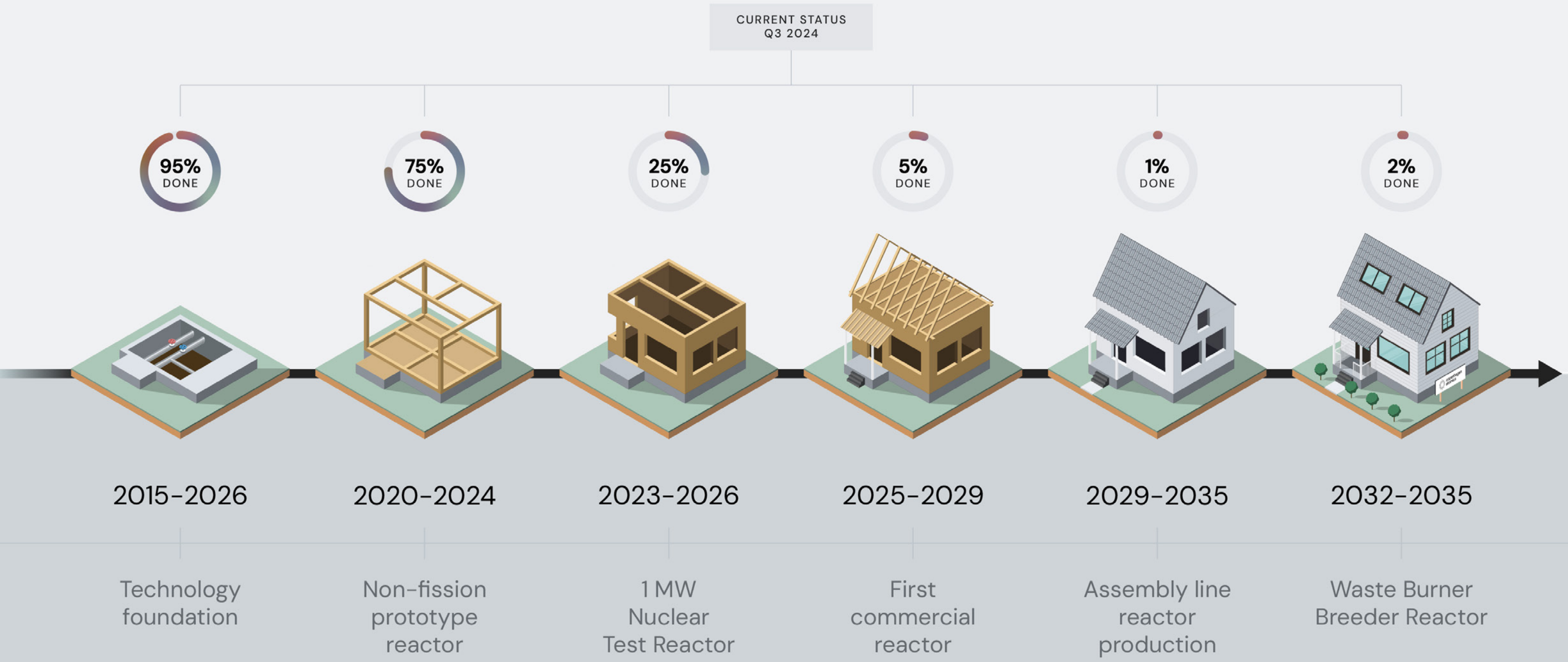


Figure 3. Milestones plan visualized as a house being constructed.

In 2015, when the four Copenhagen Atomics founders started building and testing salt systems, it was decided to focus on a thorium molten salt reactor design, which uses heavy water as moderator.

In 2015 there was a lot of technical interest in molten salt reactors, but society in general had very little interest in nuclear energy. The goal of the company from day 1 was always mass manufacturing of thorium molten salt reactors.

Why?

Because Copenhagen Atomics believes that 'the nuclear industry' needs to prove that it can provide a very significant share of global energy at a competitive price and at a much faster pace of deployment than today.

Copenhagen Atomics was founded because we knew that thorium molten salt reactors have technical and physical advantages that make them orders of magnitude more efficient than classic reactors.

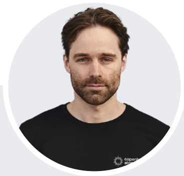
The 6 milestone development strategy laid out in this document is what will make it possible to scale from a garage startup to a major global energy company.

Copenhagen Atomics' Founder team

Thomas Jam Pedersen
Founder and CEO

M.Sc. Electrical Engineering & Software

Has a background from Nokia and multiple start-ups



Aslak Stubsgaard
Founder and CTO

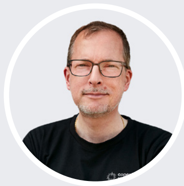
M.Sc. Theoretical Physics

Started working for DTU Space

Thomas Steenberg
Founder and VP of Critical Materials

M.Sc. Chemical Engineering & Ph.D. Material Science

Has a background of 25 years in the energy sector



Peter Szabo
Founder and VP of Administration

PhD Chemical Engineering

Is an Associate Professor at DTU Chemical Engineering

Milestone #1
Technology foundation

95%
completed

This milestone was all about creating the technical foundation in Copenhagen Atomics to enable the company to build reactors later on. Copenhagen Atomics needed to prove that we can manage molten salts, corrosion, build pumps, heat exchangers, etc. – all the basic components and technologies that the company MUST master to be able to build molten salt reactors.

Where most nuclear companies choose the paper design route to build reactors, Copenhagen Atomics chose to build and test all the components that are needed to make a reactor work.

Introducing
the molten salt loop

The heart of a molten salt reactor is essentially a closed loop where the molten salt is pumped around.

The energy is created in the reactor core and extracted in a heat exchanger. Thus, from the very beginning Copenhagen Atomics wanted to show that we could pump molten salt around in a loop and handle all aspects related to heat exchangers, corrosion, sensors, measurements, etc.

Most of this could be tested with FLiNaK in the beginning. FLiNaK is a salt which is very similar to the salts used in a real reactor, but it is not radioactive and not very expensive, thus lowering the barrier to entry.

Figure 4. A collection of molten salt test loops at the Copenhagen Atomics test center. Over the years Copenhagen Atomics has built almost 100 different test systems and sold many of them to 3rd parties with whom Copenhagen Atomics works to advance molten salt technology.

The first pumped test was achieved in 2019. As of the beginning of 2024 Copenhagen Atomics has run pumps for more than 1000 days in total. However, the systems are still being further developed and improved.

Copenhagen Atomics has built more than 10 iterations of our unique molten salt test loops (see Figure 4). These test loops are used for long-term testing of pumps, sensors, electronics and other components and they are also sold to major universities and national labs around the world to help them make molten salt research - from MIT to Berkeley and from the USA to Korea.

Copenhagen Atomics is clearly at the forefront of molten salt technology development worldwide.

Figure 5.
Left: the small pump with hydrodynamic Bearings.
Right: the first version of the AMB pump.

Copenhagen Atomics has developed a range of molten salt pumps where the 3-phase electrical motor can run at 700 °C, including a version with Active Magnetic Bearings (AMB), which means that all the rotating parts are levitating in a magnetic field and thus experience very little wear.

Because of this, it is expected that no maintenance will be required for up to 10 years even in this harsh environment with corrosive salts, 700 °C temperatures, and ultra-high levels of radiation.

Figure 6. Tanks for tonne scale molten salt production and transportation. Each tank holds 1 cubic meter of salt.

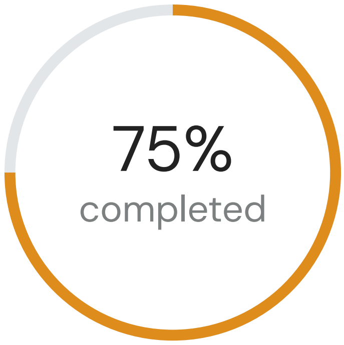
No one else in the world has as many functioning molten salt pumps as Copenhagen Atomics and we continue to improve and run extensive testing on these components.

Copenhagen Atomics has also developed more than 30 different sensors and electronics boards to be used in our reactors and we excel in molten salt purification.

Our salt production is tonnes per month and Copenhagen Atomics plans to supply nuclear grade salts to several players in the industry.

Over these last 10 years Copenhagen Atomics has obtained multiple patents relating to the foundational technologies and has also supported a number of open source projects both for software and hardware to help advance this industry.

Milestone #2
Non-fission prototype reactor



Milestone 2 is to build full scale non-fission prototype reactors in Copenhagen and test them with FLiNaK salts and later with uranium and thorium salts. These reactors cannot start a chain reaction and will therefore not produce energy.

They are electrically heated and Copenhagen Atomics can test almost everything else related to sensors, software, components, corrosion, thermal expansion, etc.

This is crucial before building the first real test reactor which is planned to run a nuclear chain reaction in 2026. Achieving milestone #2 is a major step for the company because it allows us to test all the design features and components at full scale. Copenhagen Atomics has already learned a lot from the first two non-fission prototypes and these learnings are being used in the design of the 3rd test reactor prototype which is expected to be constructed in 2024/2025.

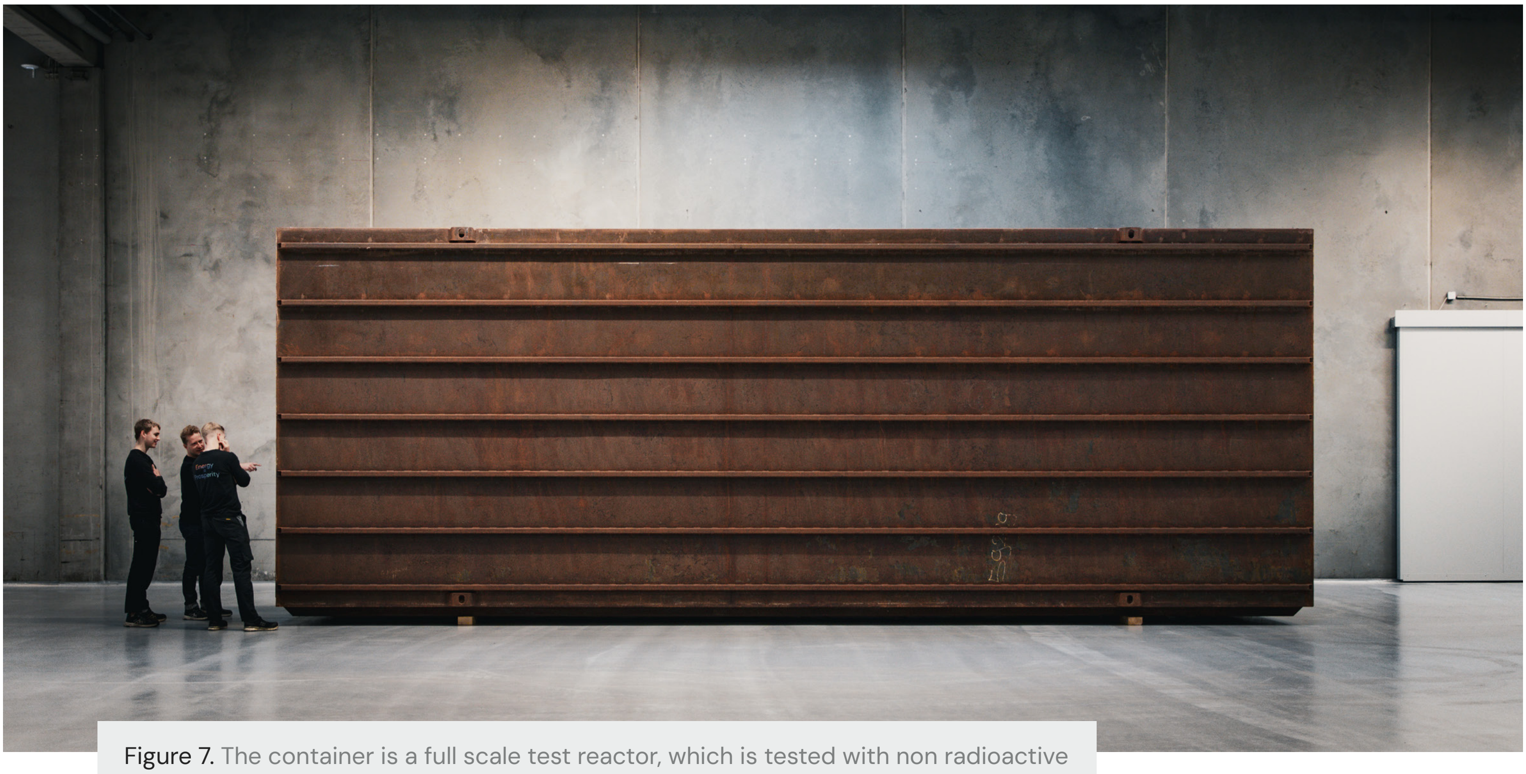


Figure 7. The container is a full scale test reactor, which is tested with non radioactive molten salts. Length: 9 meters, height: 3.6 meters width: 2.5 meters.

It is estimated to be on the order of 100 times more expensive to run tests on a full-scale non-fission test reactor than on the test loops which are shown in Figure 4.

This is why it is very important to run on the order of millions of hours of tests on the test loops before starting to mass manufacture commercial reactors. This is a big part of what Copenhagen Atomics is currently working on.

The cocoon

The reactor container is encased in a cocoon, a very large steel box with ~½ meter thick steel walls (not shown in Figure 7). The purpose of the cocoon is to protect the reactor from external impacts (such as an airplane crash), limit radiation outside the cocoon and integrate the passive decay heat system. Copenhagen Atomics expects to construct the first cocoon in 2025 with a total weight of approximately 1000 tonnes. It is shipped in sections of 40 tonnes and assembled with minimum welds on site.

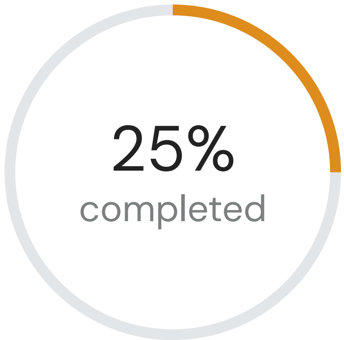
The detailed design of the non-fission prototypes is being finalized and the comprehensive testing will help determine if any changes are needed before we start building the test reactors that will create energy from fission.

The salts

Another big step for Copenhagen Atomics is to start making thorium and uranium salts containing 7Li (lithium 7, an isotope of lithium). Lithium in nature consists of ~95% 7Li and ~5% 6Li and the Copenhagen Atomics reactor needs the lithium enriched to 99.999% 7Li in order to outperform the competition, due to the fact that 6Li has ~20000 times higher neutron capture cross section than 7Li and therefore a very negative impact on the neutron efficiency of the reactor. Copenhagen Atomics has embarked on an R&D effort with the goal to create the largest 7Li production line in the world and with superior quality. In the future Copenhagen Atomics expects to sell salts with 6Li or 7Li to other players in the nuclear industry.

Note: The entire nuclear industry are unlikely consume more than 1% of the global lithium markets.

Milestone #3
1 MW nuclear test reactor



Milestone 3 is the thorium molten salt test reactor. It is planned to generate up to 1 MW of thermal output and to run for 30 days in the first instance.

The main purpose of the 1 MW reactor test is to validate the computer simulations against real world measurements. Such validation is needed for approval of the commercial reactor to operate safely for many years. Secondly, it is expected to provide proof of our technology.

Copenhagen Atomics cannot get approvals to do nuclear tests at our own factory as Denmark does not currently have an authority who has the credentials to approve nuclear reactors and the factory is not optimal for such tests. Thus, we expect to have to test it in another country.

Copenhagen Atomics has secured an agreement with the Paul Scherrer Institute (PSI) in Switzerland for a reactor test. PSI has agreed to host the test and take the lead on preparing the documentation needed for approval of the reactor test by the Swiss nuclear regulator. Switzerland is thus a clear frontrunner for the first country to run the 1 MW test reactor, but we are talking to several other countries about potentially doing a reactor test in their country.

The test reactor will be built in Copenhagen and tested with electric heating and nuclear salts. The reactor will then be disassembled and moved to the test facility and reassembled, run for 30 days and subsequently disassembled and trucked back to Copenhagen for further non-fission tests.

The 1 MW reactor is expected to have the same physical dimensions as the non-fission reactors currently constructed in Copenhagen and it is expected to be the same size as the 100 MW commercial reactors that

Copenhagen Atomics plan to deploy starting from the end of the 2020s.

The amount of heavy water and fuel salt required are also almost the same. However, the heat exchangers, pumps and pipe diameters are expected to be considerably larger in the commercial reactors to allow for the larger flows needed for the higher energy output.

Running the 1 MW reactor for 30 days means that it will only generate 30 grams of fission products[1], which will be diluted in ~3 tonnes of fuel salt, thus only ~10 ppm. This makes it easier to transport the salt and do chemical analyses on it subsequently.

> Milestone 3 is only considered 25% done because Copenhagen Atomics still need to get all the approvals to run the test reactor. This work is in progress, but it is still unclear how long it is going to take or what the total cost will be. Technically, however, there are not many uncertainties related to the 1 MW test reactor.

The first test reactor needs to be as simple as possible. For this reason it will not incorporate fuel transfer from the blanket to the core, which is a key operational aspect. It will also only remove volatile fission products.

The first test reactor is expected to run on 5% enriched 235U, with 7LiF-UF4 as fuel salt and 7LiF-ThF4 as blanket salt. Both of these salts will contain 99.995% enriched 7Li or higher. Some of the learnings from the 1 MW test may result in having to build additional test reactors and running these for some time to learn more about the detailed operation of thorium molten salt reactors.

Such additional testing might involve removing more of the fission products, testing other materials and moving 232U, 234U and 233U from the blanket salt to the fuel salt.

[1] https://en.wikipedia.org/wiki/Nuclear_fission_product

Milestone #4
100 MW commercial reactor

5%
completed

Milestone 4 is the deployment of commercial reactors. Copenhagen Atomics has not done much of this work yet, as it is paramount to focus our resources on getting the 1 MW test reactor online.

Copenhagen Atomics plans to deploy approximately 10 commercial reactor units on the first commercial site. Each of these reactor units is planned to generate 100 MW of thermal output. These reactors must have fuel transfer from the blanket salt to the core and some fission product removal in order to run for 3-5 years without refueling[2] from external sources.

Already these first commercial reactors will be a game changer for nuclear energy price points, assuming that Copenhagen Atomics can demonstrate a pathway to a carbon composite reactor core and full fission product removal in the lab by then.

This will demonstrate that molten salt reactors have the potential to outperform all other commercial reactors. By the time Copenhagen Atomics builds the first commercial reactors, we expect to have already constructed up to 5 test reactors.

Most of the components are already sourced from suppliers and the main job for the team in our factory is to assemble the components.

We ensure that our suppliers have the capacity to scale up and deliver components for more than 10 reactors in one year. This makes it similar to other industries; ordering all the components on the Bill Of Materials (BOM)

[2] Until the breeder reactor is reached in #milestone 6, refueling is needed, just like all other reactors today.

and then assembling them when they arrive at our factory.

Copenhagen Atomics actually already does this today, regularly ordering batches of components for 10 - 20 molten salt loops, 20 - 50 pumps, or 10 salt production systems from the same suppliers, respectively, and our team is already quite experienced in assembling these and making sure the quality complies with requirements.

With this in mind, Copenhagen Atomics does not foresee any major technical issues relating to production of commercial reactors. A bigger unknown at this point is what is required to get the reactors approved. In some countries nuclear regulators indicate that it will take 4 - 8 years to get such approvals. Fortunately, times are changing and we consider it likely that other countries understand that the risk profile of molten salt reactors is vastly different from classic Light Water Reactors (LWR), therefore approvals shall be fit for purpose.

> This is the reason why Copenhagen Atomics already invites people from potential deployment countries to visit our facility in Copenhagen now and start to learn how these reactors work in order for these countries to prepare themselves for this new technology.

Copenhagen Atomics expects that the reactor containers will last for ~3-5 years in the beginning. We expect to replace one reactor unit at a time while the other units on the site are running. This ensures that replacement and refueling never result in major disruption of the energy supply. Reactor core and pumps are the limiting factor on lifetime.

The plan is to store the used reactor containers on the site for the entirety of the site lifetime. Thus, nothing needs to leave the reactor building until it is time to decommission the entire plant. Please see Figure 1.

Milestone #5
Assembly line reactor production

1%
completed

Milestone 5 is about establishing assembly line manufacturing. The aim is to build the first 10 commercial reactors at our current factory in Copenhagen, but this site is not well suited for mass manufacturing.

We expect that mass manufacturing will be set up in several countries - most likely in some of the first countries to grant a type approval of the commercial reactors, because this will provide more certainty around how long it will take to install each reactor.

Ultimately, Copenhagen Atomics aims to get type approval in each country that embraces this technology, such that the reactors are approved when they leave the assembly line - similar to how airplanes are approved.

The first assembly line factory will likely have the capacity to build one nuclear reactor every day. Mass manufacturing of complex products such as cars and airplanes on assembly lines is already done today.

It is likely not more difficult to arrange the assembly of Copenhagen Atomics reactors. However, it requires substantial capital to build up the supply chain both for components, but also for thorium and uranium salts, and these suppliers will likely need to see guarantees before they commit to increased supply.

On the other hand, Copenhagen Atomics needs to make sure that if we build one reactor every day, we will actually be able to install them and get them approved. As of today, the largest uncertainty is around the installation and approval, as described above (under Milestone 4).

Even though Copenhagen Atomics has already done some planning around mass manufacturing of these reactor units, there are still large uncertainties related to how quickly production can be scaled up. Copenhagen Atomics expects that more than €10 billion is needed to scale up the supply chain and get the right agreements in place with host countries.

> For reference, an output of one reactor unit every day equals 15 GW of installed electricity capacity per year. It is expected that multiple production lines will be necessary to meet demand.

In order to understand the potential of mass manufacturing of this technology, even just one production line producing four reactors every day would result in more new electrical capacity than the total global electricity market expansion outside of China.

The chart on the page below shows that in 2024 and 2025 the expansion of global electricity demand is roughly 525 TWh/year = 60 GW = 4 reactors per day, corresponding to 57 GW of additional electricity generation – the same capacity as 1360 Copenhagen Atomics reactors (3.7 per day).

> "By the year 2100, thorium energy is likely to supply one half of all energy production in the world.
> **Why? Because price is king!**

Thomas Jam Pedersen
Founder and Chairman of the Board

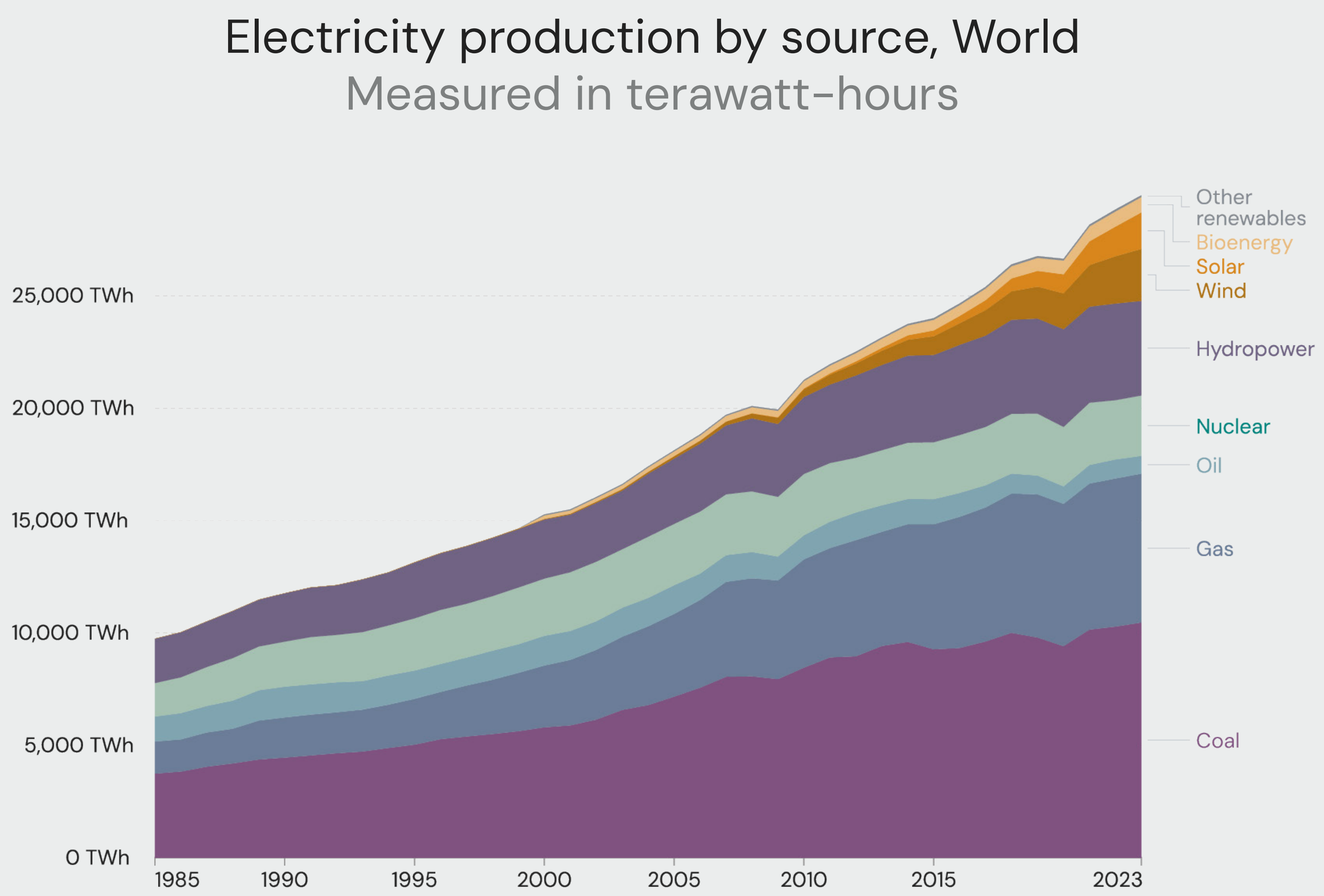


Figure 7. Electricity production by source, World
Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

Copenhagen Atomics and partners would finance, build, own and operate all of this. However, we believe this growth is only possible if Copenhagen Atomics targets other applications than grid electricity.

The expected market growth within a few commodities is more than enough to consume all this added energy capacity.

Milestone #6
Waste Burner breeder reactor

2%
completed

Milestone 6 is a very important milestone for our long term goal of an LCOE of USD 20 per MWh(e).

If Copenhagen Atomics can show that our thorium molten salt reactor can become a breeder reactor in the thermal spectrum, this has the potential of being one of the biggest advancement in the energy sector in the last 50 years.

A breeder reactor is defined by being able to generate more fissile fuel than it consumes. This means that when you start a reactor on a breeder fuel cycle, there will be no need to add more fissile fuel to it throughout its entire lifetime. In fact, you may be able to siphon off a small amount of fuel every few years, which can be used to start other reactors.

To date all nuclear reactors have run predominantly on 235U, which is a scarce resource in nature. The other fissile fuel used in reactors is 239Pu (plutonium), which is very scarce. There are only ~3000 tonnes of 239Pu globally.

However, 233U, which is created from thorium, is a better nuclear fuel than either 235U or 239Pu and therefore it can create energy at lower cost and greatly minimize the nuclear waste problem both for Copenhagen Atomics' reactors and classic reactors.

> As for thorium, there are approximately 1000 times more thorium (232Th) than there is 235U.

This is also why the reactor that Copenhagen Atomics is developing through these 6 milestones is both a breeder reactor and a waste burner.

It can take spent fuel from other reactors and minimize the time that those fuels have to be stored. In most cases the final waste from the Copenhagen Atomics Waste Burner only needs to be stored safely for 300 years above ground, vs. 100.000 years in deep geological storage, which is the norm for spent nuclear fuel from classic reactors.

Old vs New	Solid fuel reactors	CA thorium reactor	Difference
Price per kg fuel (U/Th)	€4000 (5% enriched)*	€50***	**80x**
Energy output per kg fuel**	1 – 2 GWh (thermal)	22 GWh (thermal)	**15x**
Construction time (GW plant)	4 – 15 years	6 – 18 months***	**10x**
Electricity price	60 – 120 USD / MWh (e)	20 – 40 USD / MWh (e)***	**3x**

* Source: https://www.uxc.com/p/tools/FuelCalculator.aspx
** Look up on the internet (google or ChatGPT)
*** Details available under Non-Disclosure Agreement

Figure 9. A comparison between solid fuel reactors and thorium molten salt breeder reactors. Even though fuel prices may fluctuate, it is clear that thorium breeder reactors are orders of magnitudes better than classic nuclear reactors and therefore in a class of their own. Heavy water, lithium7, fissile inventory, thorium inventory and construction steel, which is not consumed during reactor operation, is not included in this table; they are listed under CAPEX. The reactor container is a consumable, including composite material and 36 kg thorium per reactor unit per year. More information about CAPEX and OPEX are available under NDA.

All reactors currently in operation need to reload new fuel with regular intervals, typically 18 - 24 months. In fact, classic light water reactors can only use approximately 5% of their fuel before new fuel must be loaded.

This has a huge cost both because of the mining and the need for enrichment, but also because of the waste and storage requirements. A classic LWR typically needs 50 to 100 times more mining, transport, fuel, enrichment, and waste management than the Copenhagen Atomics Waste Burner design starting with transuranics as kickstarter fuel.

There is still some uncertainty as to when Copenhagen Atomics will have the first true waste burner breeder reactor. However, every step towards this design has a better fuel economy and waste profile than existing reactors.

The patents and development of the Onion Core® was started in 2020 and is one of the cornerstones in milestone #6.

Development of carbon composite materials for the reactor core is another cornerstone and this started already in 2023. This is also why Figure 3 shows more progress on milestone #6 than the previous milestone.

This will continue to be the case as Copenhagen Atomics expects more patents in this area and significant R&D efforts and testing.

2. Three sources of funding

Copenhagen Atomics has three sources of funding

Investor (equity)

Also known as hard funding

Sales revenue

Currently from purified salts and test loops

Soft funding

Research grants and (soft) loans that do not take equity

From early on Copenhagen Atomics have relied on all three sources. Currently, investor funding is the biggest with around 80%, but once we start selling uranium and thorium salts with 7Li and 6Li, sales could potentially amount to upwards of 30% of the required funding for the development phase.

The journey requires very significant funding, but Copenhagen Atomics has demonstrated an ability to continuously grow the value of the technology that we are developing. The current major shareholders agree that Copenhagen Atomics will not do an IPO until the first commercial reactors have been delivered.

Copenhagen Atomics has a policy of aiming to make it possible for investors to extract part of their investment ~5 years after their initial investment. We do this because most investors cannot be expected to wait 20 years for a return on their investment and to avoid building up pressure towards an early IPO. Copenhagen Atomics also encourages a large number of smaller private investors with B-shares without voting rights to create a community of ambassadors.

3. The six short term goals

#A Funding

The main short term funding target is to raise USD 200 million during 2024-2025. Additionally, Copenhagen Atomics will seek to potentially raise USD 20 - 100 million in soft funding mainly from the EU and Denmark. Key investors may help with soft funding and hard funding introductions.

#B Branding

The goal is to become better known among potential investors by communicating our 3 main selling points to investors:

1. Copenhagen Atomics thorium reactors have much bigger economic potential than other so-called advanced and small modular reactors, likely even bigger than fusion energy companies.

2. Copenhagen Atomics will bring our first test reactor online by the end of 2026 (but the concept was already partly proven in the 1960s).

3. Unlike most other reactor developers, Copenhagen Atomics has developed and tested the reactor hardware, putting us at the technological cutting edge.

To support achievement of this goal, the following will be implemented:

- Refining our presentation material and especially the workshop tour, aiming to provide a better understanding of the company journey and the technology risk.
- Creating a new/updated website.
- Expanding the communication team, bringing in new competences to strengthen this effort.

#C Lithium-7

The first goal for the lithium enrichment team is to demonstrate that Copenhagen Atomics can make lithium-7 at 99.99% enrichment and later that we can scale this production to tonne scale and 99.999% enrichment. This will require expanding the 7Li team significantly.

Secondly, obtaining LOIs and orders from potential customers and partners to validate the potential size of the 6Li and 7Li market. CA is unwilling to share details about our novel enrichment process.

#D 1 MW reactor test at PSI

Taking the first steps on the 1 MW reactor test project at PSI to demonstrate that the project is reality and not simply an expression of intent. The first step is to start construction of the building that houses the test reactor at PSI.

#E Uranium and thorium

The goal is to enable production of uranium and thorium salts at the required scale for reactor testing and early deployment. This entails:

- Obtaining approval from Danish authorities for handling 100 tonnes of thorium and 10 tonnes of natural uranium in Taarnby, or alternatively somewhere else.
- Securing access to buying the thorium and uranium, including setting up agreements with suppliers about establishment of uranium fluorination facilities and conversion to UF4.
- Obtaining approvals to make enriched fuel salts (5% or 10% enriched uranium) in Taarnby or elsewhere.
- Securing smooth running of the tonne scale production of salts inside the Uranium and thorium lab clean room.
- Setting up a 1000 tonne/year thorium fluorination line abroad.

#F Reactor prototype

The goal is to build the next reactor prototype (version 6.2). This version will include the cocoon and is planned to run with thorium and uranium salts in Taarnby (with natural uranium, unenriched lithium and light water).

4. Short summary

Copenhagen Atomics is a unique business opportunity.

In this document Copenhagen Atomics lays out the road map for the development of the company over the next ~10 years.

The company is in a unique position to transform the entire energy sector with thorium as a new energy source. Having access to energy at half the price will result in a reduction in costs on many products by 20 - 30%, making our reactor an extremely attractive proposition.

Thus, it is not a question of whether there are customers for this technology. It is rather a question of how soon Copenhagen Atomics can make it work and start deploying to the first customer.

When Copenhagen Atomics has started the first commercial reactor, this will represent the biggest invention in the energy sector in the last 50 years.

Thank you for your interest in us!
Looking forward to hearing from you.

Contact
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Copenhagen Atomics reserves the right to change or update information in this document at any time without prior notice.

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