Research Office
Legislative Council Secretariat

Information Note

Planning and development of underground space in selected places

IN05/19-20

1. Introduction

1.1 As an extra source of land supply, underground space ("UGS") has often been hailed as a part of the solution to land shortage in overcrowding cities by creating new space below ground for suitable uses and freeing up valuable surface land for more appropriate development.[1] This is no exception to land-scarce Hong Kong which has been finding ways to making use of subterranean resources. Over the past decades, many UGS development studies had been initiated which have also led to the realization of some UGS projects like sewage treatment works and refuse transfer station in rock caverns in the 1990s.[2] Yet, when compared with some overseas places, the types of UGS use in Hong Kong remain rather narrow, with most of them being utilities and transport infrastructures. Moreover, the regulatory framework for UGS planning and development may not be most updated to facilitate UGS development.

1.2 At the request of Hon Chan Hoi-yan, the Research Office has conducted this study to examine the use of UGS. Singapore and Helsinki of Finland are selected for study of their drivers and barriers to planning and developing UGS. Facing similar development constraints as Hong Kong, Singapore has recently accelerated its efforts to plan and develop UGS, and introduced new legislative amendments to facilitate it. Helsinki has diverse UGS uses including those for recreation and community purposes and is the world's first to draw up a city-wide master plan for UGS. This information note begins with a review on Hong Kong's UGS development, followed by a

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1 Apart from space creation, UGS may cause less environmental impacts than corresponding ground development during operation. Yet, UGS construction is more expensive and riskier, and subject to stricter fire safety, flood prevention, ventilation and even security standards.

2 As rail and road tunnels are rather common nowadays, this information note focuses on UGS uses other than rail and road tunnel. Also, rock cavern development is discussed as a part of UGS development in this information note.

brief section on the global trend of UGS uses and a detailed discussion on the development in Singapore and Helsinki. Further information on UGS uses in the two places and Hong Kong are provided in **Appendices I** to **IV**.

2. Planning and development of underground space in Hong Kong

2.1 With a land area of 1 100 sq km, Hong Kong has only developed a quarter of its land, with the rest being either protected or less suitable for development. The land constraint has geminated a high-rise and high-density development mode, while land reclamation from the sea has become an important source of land supply which has provided 25% (or 7 000 hectares)[3] of all developed land. In 2017, the Government appointed a Task Force on Land Supply to expand land resources in the long term. In its 2018 report, the Task Force, while recommending a plan of artificial islands off eastern Lantau, also acknowledged the **supplementary role** of UGS in its multi-pronged land supply approach.[4]

2.2 The Government's quest for UGS had kick-started in the early 1980s when it explored the idea of underground oil storage. As early as 1991, the Hong Kong Planning Standards and Guidelines had already covered rock cavern development ("RCD") and various UGS studies conducted over the past few decades were mostly related to RCD.[5] Despite these active studies and planning, there had only been four completed RCDs. In light of the growing land supply shortage, the Government conducted in 2012 a feasibility study on RCD and inputs were used for the formation of a **Cavern Master Plan** ("CMP") in 2016. CMP, which provides a broad strategic planning framework by delineating 48 strategic cavern areas covering 4 500 hectares,[6] intends to help the Government and private sector identify suitable sites for development, and optimize the use of UGS in cavern without compromising surface land use and development.

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[3] Over 3 000 out of the 7 000 hectares of land were reclaimed during 1985-2000.

[4] See Task Force on Land Supply (2018).

[5] Some of the major studies included the Enhanced Use of Underground Space in Hong Kong and Long-term Strategy for Cavern Development.

[6] Most areas are in urban fringe, with individual size ranging from 30 to 200 hectares for different potential uses from oil bulk storage, columbarium/mortuary, industrial, data centre, sewage treatment, refuse transfer, service reservoir, bus depot, vehicle parking, research/testing laboratories, warehousing, retail, wine storage, civic centre, performance venue, leisure and sports centre, indoor swimming pool to recreational complex (e.g. snowboarding or baseball).

2.3 Following the publication of CMP, the Government promulgated a policy in 2017 that cavern option should be "holistically considered" when conducting planning and development studies for government facilities, and in particular, assessments should be carried out for three specific uses, namely refuse transfer station, service reservoir and sewage treatment.[7] In fact, between 2012 and 2017, several feasibility studies on relocating sewage treatment works and service reservoirs to cavern had commenced.[8] Among them, the relocation of Sha Tin sewage treatment works to a rock cavern has gained initial construction funding approval from the Finance Committee in October 2018. The project will be the largest UGS space ever built in Hong Kong, with a potential of releasing 28 hectares of land in a construction timeframe of over 10 years. Other projects in the pipeline include a Diamond Hill project which is currently under site investigation and design stage.

2.4 In recent years, the Government has also renewed its interest in UGS development in **urban areas** which are not any less challenging than RCD.[9] A territory-wide study on UGS potential in urban areas was commenced in 2013,[10] which was followed by "pilot strategic urban areas" studies in 2015 for Tsim Sha Tsui West, Causeway Bay and Happy Valley, and Admiralty/Wan Chai. Among these four areas, the UGS development plan in Tsim Sha Tsui West – a five-level underground space for diverse beneficial uses for community under Kowloon Park – has been prioritized for further public engagement and detailed planning. Public views towards this plan are mixed, particularly over how the space should be used for the best community interest.[11] Some were also worried about the potential environmental impacts on the park during

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7 A Sub-Committee on Cavern Development has also been established under the Committee on Planning and Land Development which is responsible for coordinating land use planning and development of Hong Kong. See Development Bureau (2017a).

8 Studies were undertaken for relocating Sha Tin, Sai Kung and Sham Tseng sewage treatment works, and Diamond Hill, Yau Tong and Tsuen Wan service reservoirs during the period. All these projects, when realized, could release up to 45 hectares of land.

9 Although UGS developments in urban areas may improve surface environment and neighbourhood connectivity, they may face many obstacles. For example, in the 2000s, the Planning Department and MTRC had separately proposed an underground pedestrian cum retail link across Hennessy Road to relieve ground congestion. The proposals were reportedly not realized due to uncertain ground conditions and long construction schedule.

10 The study aimed to recommend 15 potential areas and review topics like the prospect of infrastructure reorganization, harbour-crossing pedestrian-cum-retail link development, and formulating guidelines for UGS development in new development areas. See Development Bureau (2014) and Wallace (2016).

11 The proposed land use comprises 40% community/pedestrian passage, 30% retail/beverage and 30% car park. See AECOM (2019) and Development Bureau (2019).

construction, location of the ventilation shafts and vehicle entrances, traffic impacts on ground during operation, and business impacts on street level retail. Apart from the Kowloon Park UGS, an underground shopping street has also been planned in northern Kai Tak area.

UGS uses in Hong Kong

2.5 Although there is a long history of Hong Kong UGS development, readily available data on UGS uses remains limited and fragmented. Based on discrete published information, the range of usage is rather **narrow**. According to the Catalogue of Tunnel published by the Civil Engineering and Development Department, there are over 570 km of underground tunnels in Hong Kong for utility purposes such as water supply and drainage, and transport facilities like railways and roads.[12] For pedestrian subways, the total length reported by the Highway Department is about 32.9 km. There are also a handful of flood prevention UGS in urban areas. However, statistics on total floor areas of commercial UGS in government and private properties is not available. Based on information of individual development projects, it is believed that car parks, plant rooms, and retail facilities built at basement levels are not uncommon; however, other UGS for community and recreational uses that can be found overseas, are generally absent in Hong Kong (See **Appendix II**).

2.6 In terms of the **location** of UGS sites, most of the existing larger scale UGS are rock caverns located in urban fringe,[13] while UGS facilities in the urban area, except car parks, are relatively rare. This may be explained by the fact that the urban area has already been intensively developed, with many intricate networks of utilities laid underground, and that most of the potentially suitable rock caverns are in less accessible and undeveloped areas. In fact, among the 48 potential locations of rock caverns identified as suitable for UGS development in CMP, about 40% of them sit within country parks or special areas.[14] As regards the **type of land** for UGS development, since most of the existing uses are infrastructures, the development tends to be government-led and funded (except those private utilities), and usually located

[12] As at mid-2019, of the 570 km of tunnels, over 200 km are water supply tunnels, 150 km rail tunnels, 110 km drainage and sewage tunnels, and the rest being road tunnels, and cable and other tunnels. See CEDD (2019c) and Wallace (2016).

[13] Two examples of cavern projects are the Island West Refuse Transfer Station in Mount Davis and the Stanley Sewage Treatment Works completed in the 1990s.

[14] Eleven of them are in Hong Kong Island, six in Kowloon, and 31 in the New Territories.

in government land. In the near future, the Government is likely to focus more on RCD, as it has commenced a study on underground quarrying with a view to developing a long-term cavern land bank.[15] There are also calls for more effective use of UGS in the urban area. For example, some have suggested developing UGS to link up buildings and facilities in busy areas to enhance the connectivity and in turn generate business opportunities.[16]

Barriers to planning and development of underground space

2.7 Despite its small size, Hong Kong is generally considered as a suitable place for UGS development. Geologically, about two-thirds of the territory has been identified suitable for RCD.[17] Economically, the high land price may make UGS investment, albeit more expensive in construction, more commercially sensible.[18] Technically, maturing tunneling technology has made construction more efficient while Hong Kong has also accumulated rich experiences and expertise in the field from its long history of UGS development. Despite these rather favourable conditions, some barriers and obstacles to UGS development may still exist. Below are a summary of the major factors affecting USG development:

(a) **Underground land rights:** while the law in Hong Kong does not specify ownership of space below surface, a landowner presumably owns the space below the land to an unlimited depth.[19] That means the development right of UGS belongs exclusively to the landowner(s), and hence UGS development by a third party under one's land may require compensation, either through a private buyout or resumption of land by the

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15 See Development Bureau (2017b).

16 See Legislative Council Secretariat (2014).

17 In Hong Kong, 85% of the underlying rocks were granite and volcanic rocks which are subject to weathering of various degrees that may affect soil quality.

18 The construction cost of underground structures could be 2 to 10 times of that of surface structures. See Hong et al. (2019) and Yong (2019).

19 For the definition of land, see Land Titles Ordinance (Cap. 585) and Conveyancing and Property Ordinance (Cap. 219). On resources below ground, see Mining Ordinance (Cap. 285) and Antiquities and Monuments Ordinance (Cap. 53).

Government.[20] Moreover, the fragmented land ownership commonly found in Hong Kong may also hinder UGS development.[21] As such, it could be more preferable to develop UGS on government land or through stipulating in the land lease the allowed UGS depth and other development requirements.[22] When discussing UGS at the Panel on Development in 2014, the Government indicated that there were ways to deal with the land title issue concerning UGS ownership beneath private developments and it would carry out detailed studies on the issue in due course;[23]

(b) **Planning framework and process:** according to the Task Force on Land Supply, there is currently a lack of "holistic planning strategy from a macro and multi-level perspective" in UGS use. Although CMP has been published, it is not a statutory land use plan and hence only serves as a guide by indicating the location of the identified sites, and their possible land uses with a view to preventing any conflict between aboveground and underground development. Cavern development in identified strategic areas will still have to go through the normal statutory planning and development process, including an environmental impact assessment.

In addition, the current statutory zoning plans, which govern the types of allowed land uses and development restrictions, do not distinguish whether the land uses are above or below ground. Unlike building height restrictions in statutory land use plans, building depth limit is not stipulated in such plans, except that the Town Planning Board has a guideline on the maximum level of basement development under open space and government,

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[20] The Railways Ordinance (Cap. 519) allows the resumption of land strata for rail construction while the Roads Ordinance (Works, Use, and Compensation) Ordinance (Cap. 370) allows the creation of easement or permanent rights of use under land, subject to compensation to the landowner. For example, in 2010, the Government reserved HK$194 million to compensate property owners the loss due to land strata resumption for high speed rail work resulting from permissible gross floor reduction and building cost rise in future redevelopment. See Transport and Housing Bureau (2010).

[21] See ARUP (2011).

[22] See《避業權爭拗 盡用政府地》，星島日報(2016).

[23] See Minutes of Meeting of Panel on Development (2014). However, it appears that the Government has not updated the Panel of the progress of the detailed studies.

institution and community zones.[24] Under the current policy, any UGS floor space developed underground is also supposed to be counted as a part of the gross floor area ("GFA") allowed, with an exemption to underground car park use;[25]

(c) **Development cost and complexities:** due to long construction lead time, and higher engineering and fire safety requirements, UGS development can be much more costly. In the case of RCD, the cost of creating such space can cost "a few times" higher than that of through near shore reclamation. A typical cavern's engineering cost may also hit as much as HK$77,000 per sq metre.[26] The high cost would discourage the private sector from financing and constructing UGS on its own. Added to this is the nuisance to the public and impact on aboveground facilities, especially for projects in urban areas. In recent years, UGS developments, in particular tunneling works, have also become notorious as cost-overrun and problems arising from difficult site conditions plagued some mega public works projects. These negative perceptions would also affect the public acceptance of UGS; and

(d) **Physical constraints and data availability:** a major potential risk of UGS development is uncertain underground conditions, whether it is related to the bedrock and soil conditions or the availability and distribution of underground utilities in the shallow subsurface. To reduce the risks, obtaining accurate and sufficient subsurface data in the format most conducive to UGS planning and development is necessary. While the Government has a long history of retaining ground investigations data,[27] and

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[24] In December 1992, the Town Planning Board introduced a guideline for consideration of planning application for underground development of commercial (excluding hotel, service apartment and office) and car park facilities beneath open space, government, institution and community zones and road. The guideline limits the development to no more than six levels and special studies on fire safety and security are required for development beyond six levels. This guideline remains in force. See Town Planning Board (2019).

[25] See Planning Department (2008).

[26] Development and engineering costs of underground space vary from case to case, depending on the site topography, geotechnical conditions, and environmental considerations. See Task Force on Land Supply (2018).

[27] The Civil Engineering Library and its Geotechnical Information Unit keep an archive of geotechnical data from ground investigations of some public and private developments. The archive is open to members of public for use.

is in the process of enhancing data format for new applications, extensive development and/or applications of three-dimensional ("3D") mapping and modeling of underground conditions are yet to be seen. In contrast, similar development and applications are increasingly popular overseas.[28]

2.8 Probably due in part to the above constraints or limitations, most existing uses of UGS have been developed under individual projects without much coherence or harmonization. In the absence of a holistic planning strategy from a macro and multi-level perspectives, the Government admits that comprehensive consideration of UGS creation and connection with the neighbouring developments still lacks in Hong Kong.[29]

3. Global trend of underground space use

3.1 Globally, UGS development has been gaining momentum in many places as cities become increasingly crowded to cater for growing urban population. Some places consider UGS as a sustainable way to contain city's uncontrolled sprawl and improving environment. Among these places, some had a long history of UGS development which could become models for other cities.

3.2 In **Montreal**, Quebec province of Canada, an interconnected network of underground pedestrian walkways (previously known as Underground City and now called RESO) has been gradually developed over the past 60 years which has now expanded into passages of 33 km long and linked up 60 residential and commercial buildings, shopping malls, universities, indoor parking, large hotels, museums, and 10 metro stations.[30] The network, apart from its attractiveness of sheltering pedestrian from cold winter, was also attributed to development incentives introduced by the city government. These include, prior to 1990, the non-calculation of floor space in underground development, even for retail uses, in maximum permissible gross floor space. Although the network has brought tremendous benefits to commuters, there

[28] See European Cooperation in Science and Technology (2016).

[29] See GovHK (2019).

[30] It was estimated that about 80% of downtown Montreal's office space and 35% of commercial space could be accessed through the network, and about 500 000 passed the network each day.

had been concerns over the underground city's negative impacts on street-level business in the area.[31]

3.3 **Japan** is another widely cited example of UGS development. It has put diverse facilities underground from liquid petroleum gas storage to rails, shopping mall and pedestrian walkway. In particular, underground shopping streets connecting to rail and metro stations are a common feature in most Japanese cities, which have provided more than 1.1 million sq metres of space nationwide. The extensive use was partly owed to the rapid economic growth in the 1960s and 1970s, and building height restriction introduced for earthquake mitigation. In the past, there was no restriction as to the depth of construction and a lack of coordination as to which uses should be located in which subsurface stratum. These have led to competition and conflicts for development.[32] Against this background, the Japanese government introduced in 2001 a legislation that distinguishes shallow from deep UGS.[33] Since then, subsurface space below 40 metres or beyond 10 metres below the bearing surface of the building foundation can be reserved for "public uses" without compensation to the landowners.

3.4 In **Taiwan**, the underground shopping streets have also been a tourist attraction. Although the first underground shopping street was developed in Kaoshiung in the late 1960s, the city of Taipei caught up since the 1980s when the city metro system was built. Now, Taipei has at least 6 such streets in operation, with some of them connecting to the Taipei Station and the longest one (over 800 metres long) providing space for over 180 shops. These streets are either separately developed by the city government or developed in tandem with the metro construction. In some of these streets, there are also government facilities including service centres for local residents.[34]

3.5 In the **Netherlands**, UGS has come to the attention of regional authorities in the late 1990s after public concerns over excessive road planning and development on land surface throughout the country. It subsequently led to a joint study by the most developed regions in the west including

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31 See El-Geneidy (2011).

32 See Bobylev (2009).

33 The legislation is the Act on Special Measures concerning Public Uses of Deep Underground.

34 See 臺北捷運(2019).

Amsterdam and Rotterdam to explore the viability of UGS.[35] In Amsterdam, underground space has been developed into bike parking, car parks and utility tunnels. To facilitate the UGS development and improve underground data availability and accuracy, since 2018, the Netherlands has also made it mandatory for developers to share geological/geotechnical data including soil structure and groundwater from site investigation with the central registration service, called Key Registry for the Subsurface. Developers are also obliged to report to the registry any inaccurate data.[36]

4. Planning and development of underground space in Singapore

4.1 Facing similar land shortage as Hong Kong, Singapore has also been relying on land reclamation to meet its space needs. During 1965-2014, the city's land size grew by 22% through reclamation. Yet reclamation has become less sustainable due to growing boundary constraints, increasing water depth for reclamation, and rising sand costs. High rise development also faces more limits from aviation and national defence needs.[37] Hence, Singapore began to turn to UGS as an alternative source of land. Since the 1990s, there have been sporadic UGS developments (excluding railway). The largest UGS developed so far was the ammunition storage in rock cavern opened in 2008 which was able to free 280 hectares for other uses.

4.2 A key milestone of UGS development in Singapore was 2007 when an inter-agencies Underground Master Plan Task Force, led by the Ministry of National Development, was set up to develop an **underground master plan** and identify potential projects.[38] In 2010, the high level Economic Strategies Committee elevated UGS use to a strategic level, and made recommendations of (a) developing an underground master plan to ensure that underground and aboveground spaces are synergized; (b) developing subterranean land rights

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[35] In Amsterdam, the city had approved a massive plan in 2008 to build a US$14 billion (HK$109 billion) underground city under the canals in the city. The plan, capable to create over 1 million sq feet of retail, leisure and parking facilities, will require 20 years of construction from 2018. However, there is no updated news of the plan's progress. See The Telegraph (2008).

[36] See Zeiss (2017).

[37] Generally, buildings in Singapore should not be taller than 280 metres. In Hong Kong, building height restriction depends on building location, and the impact on ridgeline.

[38] The need for a master plan was highlighted after a proposed underground alignment of a strategic sewage tunnel almost clashed with a proposed metro line. However, the Task Force still faced many difficulties including the lack of sufficient and accurate geological/geotechnical data. See Zhou (2011).

and valuation framework to facilitate UGS development; (c) establishing a national geology office;[39] and (d) investing in creation of basements in conjunction with new underground infrastructure projects (e.g. rail).

4.3 In order to enhance the coordination of the work for UGS development, a Steering Committee on Underground Development was established in 2013, and an Underground Works Department under the Urban Redevelopment Authority ("URA") was set up in 2014. Generally, UGS has become a default option for major utility and infrastructure developments and government agencies must justify their decision of not going underground. And the priority is to house underground rail, utilities, warehouses and storage.[40] In 2018, URA also completed a benchmarking exercise on UGS development to examine international experiences and identify gaps in the planning process. This is followed by the release of Singapore's draft Master Plan in 2019, a statutory land use plan mapping out permissible land use over the next 10 to 15 years, which for the first time also included **underground plans** for three districts, namely Marina Bay, Jurong Innovation District and Punngol Digital District.

UGS uses in Singapore

4.4 The UGS uses in Singapore appear to be a bit more diverse than Hong Kong, though they have also similarly concentrated on infrastructures and utilities (See **Appendix III** and **Figure 1**). Existing RCDs in Singapore are rather limited in number but two of them (i.e. the ammunition and oil storage) appear to be bigger in size than Hong Kong's existing RCDs. Singapore also has a 20 km long common services tunnel housing various utilities pipes in Marina Bay. To further exploit UGS, Singapore is planning some **innovative development**, including constructing a power substation below ground with a commercial development atop. In particular, a new underground air-conditioned bus interchange has also been scheduled to commence operation soon. There was also a trial on underground bike parking, costing S$4.7 million (HK$27.3 million) to develop, to support the city's sustainable mobility vision, though the trial has been discontinued in late 2019 due to low usage.

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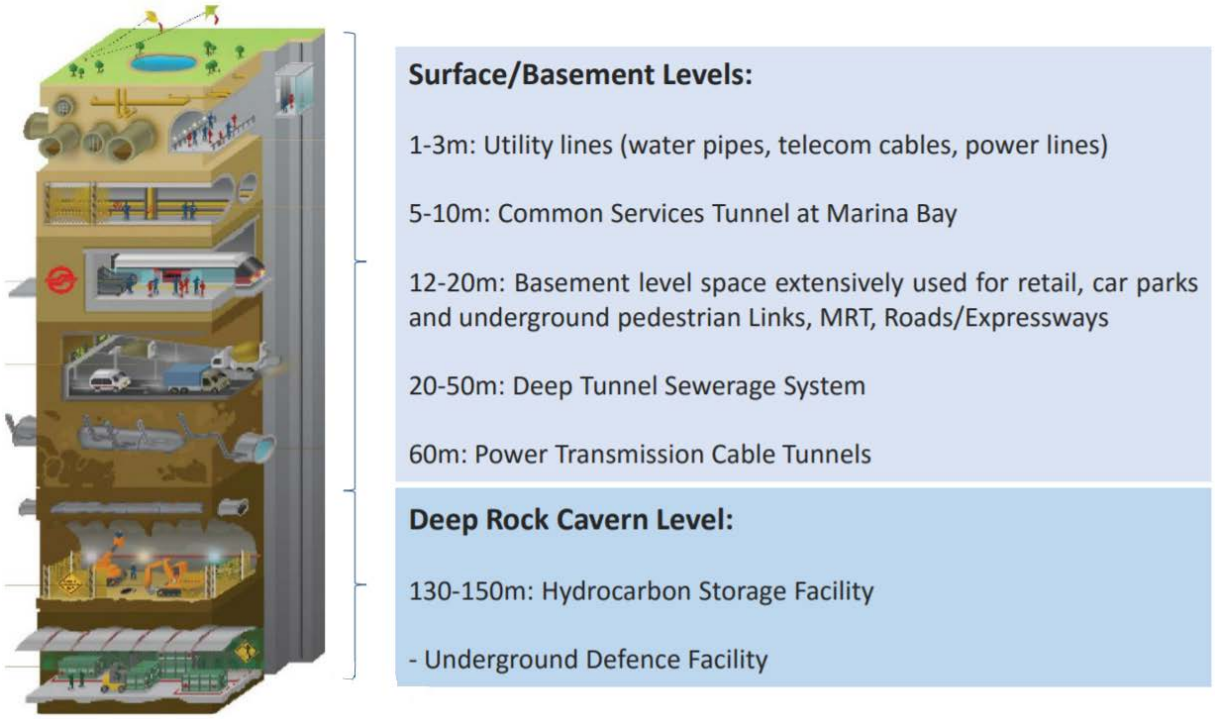
[39] The Geological Office was established in 2010.

[40] In 2015, a Coordinating Minister for Infrastructures was also appointed to spearhead various developments.

Figure 1 – Illustration of types of facilities housed beneath Singapore land



Source: Singapore Land Authority.

Measures to support the planning and development of UGS in Singapore

4.5 Like Hong Kong, the high land price in Singapore may have made it more commercially attractive to create UGS, despite higher construction cost of UGS. However, its geological conditions may be more challenging than Hong Kong as the terrain is relatively flat with thick weathered soil in the surface layers. Despite that, Singapore seems to have a forward-looking mindset to facilitate future planning and development of UGS. Below are some of the key measures taken:

(a) **Restructuring underground land rights:** the State Lands Act provides that a landowner owns the underground space to a depth that is "reasonably necessary for the use and enjoyment of surface land". However, the law had been not exactly clear over such depth. An amendment was therefore made to the law in 2015, which provides that a landowner can only claim their rights of **subterranean land up to 30 metres below Singapore Height Datum** if the depth is not specified in the land lease,[41]

[41] Singapore Height Datum refers to the average historical sea level of Singapore.

and beyond that the land has become state-owned.[42] However, landowners will continue to have a right to construct building piles to the depth necessary to provide support for surface development, including the depth within the state-owned strata. This amendment can provide the certainty on ownership boundary for planning UGS uses;

(b) **Acquisition of land strata:** apart from depth restriction, another amendment to the Land Acquisition Act passed at the same time allows the government to **resume any specific stratum space for public purpose**. This arrangement hence can avoid the need for resuming the entire column of land, and any development aboveground. The landowners will be compensated, with the level determined by factors such as the market value of the surface land. The amendment can facilitate the future development of UGS by both the government and private developers;

(c) **Development of underground modeling and mapping:** the Building and Construction Authority has already established a **3D geological model** for its deep bed rock in 2018, by making use of its 60 000 boreholes data (up to 200 metres deep) collected from government departments and construction companies. It is currently developing another model for shallow subsurface (less than 60 metres) above bed rock so that it could be combined with the former to form a unified 3D geological and geotechnical model. The modeling may help better planning of underground space development and reduce risks and costs.

In addition, **3D underground maps** known as the Special and Detailed Control Plan, which shows the existing and planned underground infrastructures and utilities, are also being developed for the whole Singapore. Such mapping has been completed for three pilot areas of Jurong, Punggol and Marina Bay (See **Figure 2**), when the Singapore Master Plan was

[42] The figure of 30 metres is considered as "reasonably necessary for the use and enjoyment of surface land". The level was determined after consultation with the industry, lawyers and academics, and an examination of existing known basement depths of Singapore buildings. The usual building basement extends to an average of 15 metres below ground, according to the Singapore government. See Parliament of Singapore (2015).

unveiled in March 2019.[43] URA also plans to develop similar plans for deeper space for rock cavern development;

Figure 2 – Extracts of the underground map for Marina Bay

Source: Urban Redevelopment Authority.

(d) **Financial incentives to facilitate development of a comprehensive underground pedestrian network:** in order to incentivize the development of an underground pedestrian network in the traditional shopping icon Orchard Street, URA had rolled out an incentive scheme providing **cash grant rebate** – calculated at a fixed sum of S$28,700 (HK$167,000) per sq metre ("psm") of space built under state-owned land and $S14,400 (HK$83,500) psm under private land – to any property developers or owners who invest in building selected underground pedestrian walkways. The incentive scheme was first introduced in 2004 and enhanced in 2012 with the granting of a **bonus development right** capped at 10% of gross floor area.[44] Reportedly the response had been lukewarm, as individual property owners had concerns over the time and cost of development, and possible loss of shoppers to competitors through the pedestrian network. To help alleviate the cost concern, the amount of cash grant was increased further in 2016 which was valid until 2018; and

(e) **Funding research and development:** the Singapore government has also invested in supporting innovation and research in UGS

[43] Each map shows the facilities like pedestrian links, car parks and utilities up to 8, 15 and 25 metres. The plans will help coordinate planning of the uses of UGS, and increase transparency for developers. See Strait Times (2019a).

[44] See Urban Redevelopment Authority (2016).

development under the S$135 million (HK$784 million) **Land and Liveability National Innovation Challenge** to "create new space cost-effectively" and "optimize the use of space". The aims of the initiative are to develop usable cavern, explore the feasibility of creating UGS in areas of poor soil, and study the human well-being and comfort in UGS.[45]

4.6 While Singapore has passed what it regards as facilitating legislation to provide certainty on ownership boundaries for both government agencies and landowners to plan for the use of UGS, there appears limited public discussion on the impacts and cases of invoking the laws for new UGS development.[46] It may still be premature to assess their effectiveness given the complexity of land matters and lengthy planning process. Nevertheless, the changes are considered a positive step to facilitate Singapore's long-term planning for the development and productive use of UGS in the future.

5. Planning and development of underground space in Helsinki, Finland

5.1 The city of Helsinki is a compact city by European standard, with more than 10% Finland's population (640 000) in just 0.07% (215 sq km, which is one fifth the size of Hong Kong) of the country's land area.[47] Helsinki had also resorted to reclamation to meet its space needs. About 12% of the city's area is reportedly developed from reclamation.[48] Unlike Hong Kong and Singapore, development in Helsinki remains low-rise, and a general restriction for constructing tall buildings applies in the downtown area in order to preserve the city landscape.[49] As such, demand for land within the city has been constantly strong for different kinds of development.

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45 See National Research Foundation (2018).

46 There were also suggestions that the revised ownership and land acquisition framework has yet to be complemented by other technical matters addressing the first right of use of UGS and movement of fluids below ground. See Zhou (2016).

47 Helsinki Metropolitan Area comprises four municipalities namely the city of Helsinki, Vantaa, Espoo, and Kauniainen. The Helsinki Region includes 10 more municipalities around the metro area, though their population is just around 300 000.

48 See Timeout (2016).

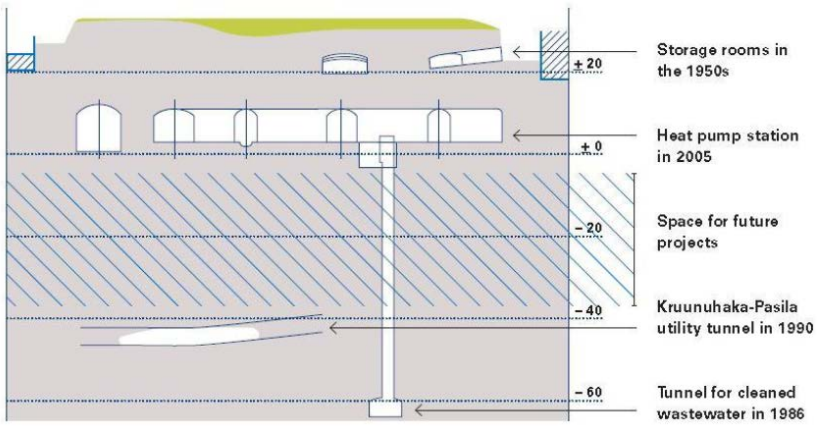
49 By 2017, Finland's tallest building was 90 metres and located in a municipality adjacent to the city of Helsinki.

UGS uses in Helsinki

5.2 Helsinki has tapped into its underground land resources since the 1960s and the number of UGS developed has grown significantly. By 1989, only 4.5 million m^3 of UGS had been developed. Ten years later, the amount of space rose by a third to 6 million m^3 in 1998. By 2018, the space further doubled to 12.7 million m^3, with an estimated total floor area of 2 million sq metres. So far, the city has already built 336 UGS spaces and 293 km tunnels for various purposes.

5.3 Compared with Hong Kong and Singapore, Helsinki has more **diverse** uses of UGS (See **Appendix IV**). Not only infrastructures and utilities like sewage treatment plants but also community and recreational uses like swimming pool, church and children playground have been put below ground. In some cases, the UGS use is for dual-use which for example, allows UGS facilities to be turned into emergency shelter. To optimize underground land use, multiple underground facilities could be placed at different depths in a single location (See **Figure 3**). UGS development in the city centre is not uncommon too, as represented by the construction of a service tunnel known as "KEHU",[50] underground shopping facilities and inter-linked car parks. It is estimated that up to 20% of the retail space in the downtown area is below ground, amounting to 90 000 sq metres.[51]

Figure 3 – Multiple UGS facilities at different depths at Katri Vala Park in Helsinki



Source: City of Helsinki Real Estate Department.

[50] See PIARC (Undated).
[51] See City of Helsinki (2019d).

Measures to support the planning and development of UGS in Helsinki

5.4 Helsinki is widely regarded as a suitable place for UGS development though it has a relatively flat terrain. Geologically, the bedrock is close to the ground at an average depth of seven metres. Economically, the rising housing price in Helsinki has made UGS more attractive, while good accessibility to bedrock resources and high bedrock quality (i.e. hard granite) also mean lower tunneling cost.[52] Socially, the Finnish cultural preference for open space also lends strong support for relocating facilities underground to free surface space to meet people's aspirations for high quality of living.

5.5 It is worth noting that despite its vibrant UGS development, Helsinki has not enacted any law specifying the underground land rights or the boundary to which land ownership may extend below ground.[53] According to the city government, it is generally presumed that the landowner owns the UGS beneath surface, but in practice the landowner can only have a right to use the UGS and such use is by norm confined to a depth of six metres.[54] Below are the measures in Helsinki that have probably helped drive the development of UGS:

(a) **Enactment of an underground master plan ("UMP"):** Helsinki has enacted and published in 2010 the world's first UMP which **allows the control over the locations and space allocations of new, large and significant underground facilities, traffic tunnels and their interconnections**[55] (See **Figure 4**). As a dedicated plan and part of the land use planning process of Helsinki, UMP arose from the need for better coordination and planning of existing and future development of UGS which has been and will

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[52] It was once estimated that the average price for UGS space was EUR 100/m^3 including excavation, rock reinforcement, grouting and under-drainage. The lower price may be due to the common use of conventional drill and blast method in tunnelling, rather than tunnel boring machine and the less use of cast concrete lining in hard rock condition. See Vähäaho (2018).

[53] A committee appointed by the Finnish Ministry of Environment had reviewed the legislation and planning procedures of UGS development in Finland. In its report published in 1990, it was recommended that the law and regulations governing aboveground development should apply to underground too. However, in relation to subterranean ownership, the committee did not make any recommendation on it.

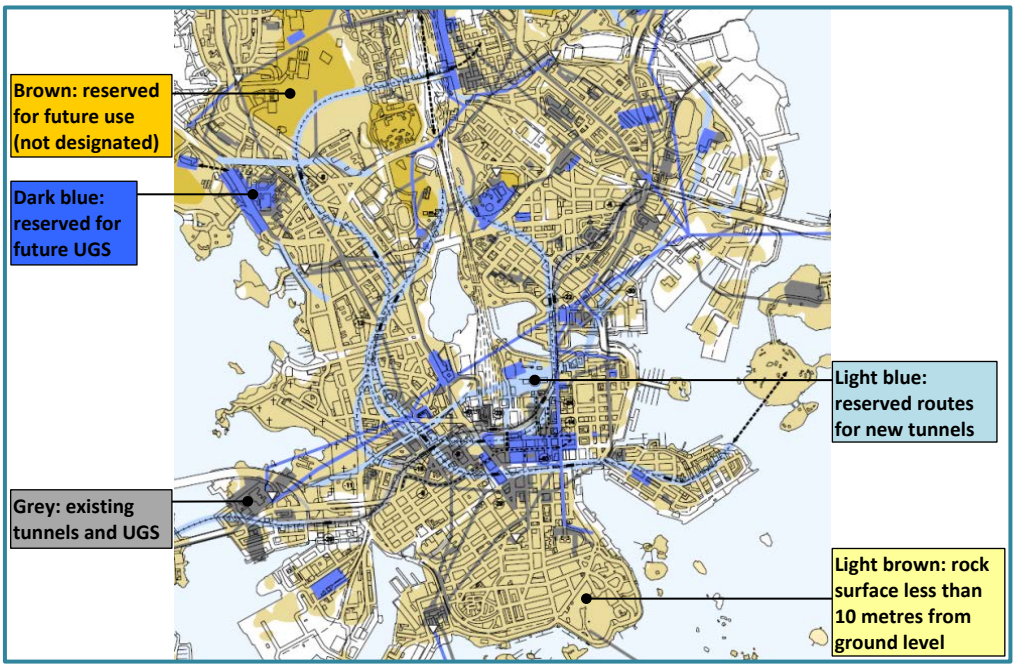
[54] Generally, building underground has been common in Finland where a civil defence shelter must be built beneath building with a total floor space at or over 1 200 sq metres and such shelter is normally about one to two storeys, or about six metres. See Vähäaho (2014).

[55] The enactment of UMP was a lengthy process that involved public consultation and engagement between 2000 and 2010. See Vähäaho (2014).

be growing in number, and once built, cannot be easily converted to other uses. It can therefore help reduce the potential conflicts between not just competing UGS uses but also aboveground and underground developments.[56]

Hence, UMP has the following functions: (i) reserves designated space for public utilities and important private utilities over the long term; (ii) provides a framework for managing and controlling the city's underground construction work; and (iii) allows suitable locations for unclassified underground use in the future. A map has also been published to show the locations of existing, planned, and reserved UGS in Helsinki, and potential shafts and access to future UGS are also reserved to ensure that future development will not be hindered by the lack of space for such interface with the ground level. According to the City of Helsinki, there are about 40 rock resource reservations, with a total area of almost 1 400 hectares which represent 6.4% of the land area of Helsinki;

Figure 4 – An extract of the underground master plan of Helsinki



Source: City of Helsinki.

[56] Helsinki had implemented a UGS allocation plan since June 1986 which was based on the existing and long term needs for rock caverns by public agencies including municipal facilities, civil defence shelter, and city transport.

(b) **Right to UGS use arrangement:** while the legislation does not define the extent of ownership below ground, property owners can generally build and use no greater than a depth of six metres by tradition, which is generally sufficient for building one or a maximum of two underground levels. If landowners wish to build multiple underground levels beyond six metres, they will need to seek approval from the city authority. The Helsinki government has thus stated "there is a difference between the right to use property and the ownership of land". According to some reports, the Helsinki government charges companies using UGS only 50% of the ground level rent to facilitate UGS development.[57] For public projects beneath the property, the landowner may only restrict or seek compensation for the use of UGS, if the use causes harm or loss to the landowner; and

(c) **Establishing geological/geotechnical database:** abundant and accurate geological and geotechnical data is crucial in UGS, as uncertainties in underground conditions may result in work delay and cost overrun. In this regard, it has been a statutory requirement for ground **investigation data to be submitted to the city authority** at the planning stage of every development and the data would be incorporated into its geotechnical information database.[58] This practice has helped accumulate rich geological and geotechnical database, which was established as early as 1956, and now contains data of at least 240 000 boreholes and data from 5 000 ground water monitoring tubes. Such information, including details of existing and planned foundations and tunnels, has been available for the public, developers and professional for use at a nominal cost.[59]

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[57] See, for examples, European Cooperation in Science and Technology (2016) and City of Helsinki (2009). In replying to an enquiry over the charging details filed by the Research Office, the City of Helsinki government stated that the rule was a "custom" in Helsinki adopted since early 1980s.

[58] According to the Land Use and Building Decree, ground investigation reports are submitted for application for building permits. See Paul (2002) and Vähäaho (2011). The Research Office has also written to the City of Helsinki to enquire further details about the data sharing requirements but a reply is still pending.

[59] See Chow (2002).

5.6 Seven years after the approval of the first UMP in 2010, the City of Helsinki has begun reviewing the UMP in 2017 as some UGS needs have become obsolete while some new needs have arisen. The new plan aims, among others, to further diversify the uses of UGS, and ensure the safety of the UGS facilities. It will also address the priorities and directions laid down in the overall city strategy and plan. One of the directions under study is to create a more comfortable walking environment by diverting more traffic from streets,[60] while another is to create more retail space in order to maintain the competitiveness of the downtown Helsinki area as retail rental has soared up amid growing demand for retail space.[61]

6. Observations

6.1 Hong Kong has been developing its UGS resources to supplement its land supply since the 1980s, and has achieved progress in the planning and development of rock cavern. It has also drawn up a cavern master plan to identify potential sites and uses. The Government has made internally rock cavern a default option to consider for selected public infrastructure planning. Albeit the progress, widening the use of UGS will likely remain challenging, especially in urban area. In addition to cost, time and technical barriers, land ownership under the current legal framework may hinder UGS development in the long term. Probably because of the land ownership complexity, most of the larger scale UGS developments, regardless sitting in urban area or urban fringe, are for public facilities and under government land.

6.2 In Singapore, while its experience in planning and developing UGS is comparable to that of Hong Kong, the island state appears to be more proactive and strategic in its development. This is indicated by the legislative amendments to give UGS a clear and transparent planning and development framework, as well as the drawing up of subterranean maps of selected districts. Although how the legal changes have pushed forward UGS development in Singapore is yet to be seen, the move is considered a paradigm shift to provide clarity conducive to greater use of UGS. To encourage private sector participation, Singapore has put in place an incentive scheme for private developers building selected underground pedestrian links in central area. Since the response was reportedly rather lukewarm, the experience might

[60] See City of Helsinki (2019a).
[61] See City of Helsinki (2019d).

suggest that great challenges remain in developing UGS, especially at locations with many already-built facilities above ground.

6.3 In Helsinki, the boom in UGS development owes a great extent to favourable geology and a long history of such development. With a favourable bed rock condition, construction costs are reportedly lower. Its UMP, through controlling the space allocation of large UGS facilities, has contributed to an orderly and coordinated planning and development. While there is no law defining the extent of subterranean ownership, landowners in practice may use UGS up to six metres depth. This traditional norm might also have eased the process in developing UGS in Helsinki. Both Singapore and Helsinki have made efforts to strengthen the geological database, which is helpful for macro planning. Based on the experiences of the overseas places, apart from climatic, geological and cultural factors, a clear legal framework in UGS ownership and use, alongside a visionary master plan, is crucial to UGS development, even though extensive development across the city may take as much as decades of time.

Appendix I

Table – Planning and development of underground space ("UGS") in Hong Kong, Singapore and Helsinki of Finland

	Hong Kong	Singapore	Helsinki, Finland
City characteristics			
Land area (sq km)	• 1 107.	• 719.	• 215.
Population	• 7.5 million.	• 5.6 million.	• 643 000 (City of Helsinki).
Climate	• Subtropical – hot and humid.	• Tropical – hot and humid.	• Continental – cold and humid.
Amount of underground space developed	• No available figure.	• No available figure.	• 2 million sq metres of floor space.
Underground space rights			
Law/provision stipulating underground space rights	• No specific law/provision.	• State Lands Act.	• No specific law/provision.
Maximum depth of land ownership	• Landowner owns land beneath surface indefinitely.	• Landowner owns and uses land up to 30 metres deep, subject to the need of building foundation works.	• Landowner owns land beneath surface but their right to use is by practice limited to six metres in depth.
Resumption of specific land stratum by Government	• Allowed for public purpose under certain laws such as the Railways Ordinance.	• Allowed under Land Acquisition Act since 2015.	• Use of land strata for public projects allowed but landowner should be compensated if there is harm or loss to the landowner for UGS use.

Table – Planning and development of underground space ("UGS") in Hong Kong, Singapore and Helsinki of Finland

	Hong Kong	Singapore	Helsinki, Finland
Planning framework			
Dedicated underground land use/master plan	• Cavern master plan only.	• Underground plans for three districts, released as part of the master plan.	• City-wide underground master plan.
Whether the dedicated land use or master plan has legal force	• No. Only used as a tool to guide planning process.	• The master plan is a statutory land use plan.	• It is legally binding.
Others			
Incentives for UGS development	• Underground car park exempted from gross floor area calculation.	• Cash grant rebate and bonus development right for building underground pedestrian walkways.	• Not specifically listed by the city government; but the city government only charges half of the market rent for using underground space.
Availability of geological /geotechnical database	• Data are kept in Civil Engineering Library and an online portal only open to consultants.	• A 3D geological data model is being developed. • 3D underground maps for some districts are published.	• Developers are required submit to the authorities geotechnical data which are put into a database for public use.

Appendix II

Table – Examples of underground space uses in Hong Kong

Type of use	Examples	Descriptions	Development period, cost and status
Utilities/storage			
Deep sewage tunnel	• Harbour Area Treatment Scheme.	• 44 km long and average depth of 100 m.	• 1994-2001 (first stage) and 2009-2015 (second stage).
Sewage treatment	• Stanley Sewage Treatment Works.	• 130 m long, 17 m high and 17 m wide.	• Completed in 1994.
	• Sha Tin Sewage Treatment Works.	• 1.34 km long. • 28 ha of land saved.	• Under construction.
	• Sham Tseng and Sai Kung treatment works.	• 1.1 ha and 2.2 ha of land saved respectively.	• Feasibility studies completed.
Refuse transfer	• Island West Refuse Transfer Station.	• 60 m long, 12 m high and 27 m wide.	• Completed in 1997.
Power cable tunnels	• Nam Fung – Parker by Hongkong Electric.	• 5.7 km long.	• 1990-1993.
Explosives depot	• Kau Shat Wan, Lantau.	• 20 m long, 6.8 m high and 13 m wide.	• Completed in 1997.
Fresh or salt water service reservoirs	• Western water service reservoir.	• 4 000 m^2 of land saved for open space purpose.	• 2007-2009. • HK$500 million.
	• Diamond Hill service reservoir.	• Under site investigation and design stage.	
	• Yau Tong, Tsuen Wan and Lam Tei service reservoirs.	• Under study.	
Storm water storage	• Tai Hang Tung.	• 100 000 m^3 in capacity.	• Completed in 2004.
	• Sheung Wan.	• 9 000 m^3 in capacity.	• Completed in 2009. • HK$200 million.
	• Happy Valley.	• 60 000 m^3 in capacity.	• 2011-2018. • HK$1 billion.
Traffic/pedestrian			
Underground space for mixed uses	• Beneath Kowloon Park.	• Under planning.	
Underground shopping street/passage	• North Kai Tak area.	• 1 500 m long and to be built and operated by private developers.	
Car park	• Automated underground car park in Sham Shui Po.	• Under study.	

Table – Examples of underground space uses in Singapore

Type of use	Examples	Descriptions	Development period, cost and status
Utilities/storage			
Deep sewage tunnel	• Across city.	• 48 km of main tunnels. • 110 ha of land saved.	• 2000-2008. • S$3.4 billion (HK$18.7 billion).
Power cable tunnel	• Across city.	• 35 km long and 60 to 80 m below ground.	• 2012-2018; 5 years. • S$2.4 billion (HK$13.9 billion).
Common Services Tunnels	• Marina Bay.	• 20 km long for telecom cables, power lines, water, and trash collection pipes.	• 2008-2014. • S$548 million (HK$4,274 million) (owned and operated by the government).
Ammunition storage	• Mandai Quarry.	• 280 ha of land saved.	• 1999-2008.
Liquid hydrocarbon storage	• Jurong Rock Cavern.	• 130 m below seabed. • 1.47 million m^3 in capacity and 60 ha land saved.	• 2007-2014. • S$950 million (HK$5,814 million) (second phase under planning).
Water desalination plant	• Marina East.	• 3 ha land saved.	• To be completed by 2020.
Power substation (230 kV)	• Pasir Panjang.	• 3 ha land saved. • Commercial development atop.	• Under planning for completion by 2025.
Service reservoir	• Bidadari service reservoirs.	• 7 500 m^3 in capacity.	• Under construction since 2017 for completion by 2022.
Community/recreation			
Bike parking	• Next to Admiralty MRT station.	• 500 bikes (automated parking).	• Opened in January 2018 for trial and closed since 28 December 2019. • S$4.7 million (HK$27.3 million).
Science city	• Kent Ridge.	• To house 4 200 workers.	• Under study.
Traffic/pedestrian			
Bus interchange	• Bidadari.	• 18 bus lots and air conditioned.	• Scheduled for completion in 2019.
Pedestrian streets with shopping space	• Marina South – City Link Mall.	• 1.8 ha (60 000 sq ft.) mall space (first underground mall in Singapore).	• Opened in 2000.
Hub parking	• Punggol district.	• Interconnected underground car parks.	• To be open progressively from 2023.

Appendix IV

Table – Examples of underground space uses in Helsinki

Type of use	Examples	Descriptions	Development period, cost and status
Utilities/storage			
Sewage treatment	• Viikinmaki sewage treatment plant.	• 15 ha in size. • Residential use atop.	• 1988-1994.
Utility/ technical tunnels	• Across Helsinki.	• 300 km long in total.	• 60 km shared by utilities like district heating, power, water supply, telecommunications.
Data centre	• Beneath Uspenski Cathedral (in an old bomb shelter).	• 30 m below ground.	• Opened in 2010.
District /heating and cooling	• Under Katric Vala park.	• 50-90 m below ground.	• Opened in 2006.
	• Under Esplanade Park.		• Opened 2018.
Service tunnels	• Known as KEHU for delivery vehicles carrying store supplies in downtown.	• Over 3 km long and up to 35 m below ground.	• Completed in the 80s, and between 2005 and 2010 • US$80 million (HK$624 million).
Community/recreation			
Church	• Temppeliaukio Church.	• 750 seats.	• Opened 1969.
Swimming pool	• Itäkeskus swimming hall cum gym.	• 11 000 m^2 in floor area.	• Completed in 1993. • Dual use as a defence shelter for 3 800 people.
Museum	• Amos Rex.	• 22 000 m^2 in floor area.	• Opened in 2018. • €50 million (HK$462.5 million).
Sports	• Formula Center for karting.	• 300 m long.	• Dual-use as an air raid shelter.
	• Hartwall Arena - ice hockey rink.	• 31 m wide and 20 m below ground.	• Along with a 350-seat restaurant.
Children playground	• Arena Center Hakaniemi and Leikkiluola playground.	• 30 m below ground.	• Opened in 2003.
Culture events venue	• Garden Arena.	• 120 000 m^2 in floor area.	• Under construction.
Traffic/pedestrian			
Bus terminal	• Kamppi Bus Station.	• 25 000 m^2 in floor area.	• Opened in 2005. • €150 million (HK$1,452 million) • Link with commercial and shopping centre atop, and rail station.
Car parks	• Tapiola.	• 96 000 m^2 in floor area (2 000 spaces).	• Completed in 2013 and 2016.

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6 March 2020
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