Key Takeaways

- China's sanitation strategy emphasizes the expansion of underground sewers with government funding and treatment targets bolstering the construction of piped sewer networks and centralized treatment plants. However, unlike most countries that fully transition households (HHs) to sewers, Chinese HHs continue to utilize onsite septic tanks for primary treatment.
- Because of this, nearly 100% of China's population is reliant, in some way, on onsite sanitation (OSS) requiring a blend of fecal sludge management (FSM) and sewage treatment. With only a few examples of new construction abandoning septic tanks, this practice is expected to continue.
- In light of China's renewed commitment to tackling persistent water pollution, FSM may grow in importance in the coming years. Drivers exist that suggest there may be increased receptivity towards non-sewered sanitation solutions in rural areas, where systems are already trending towards decentralization and cost minimization is of great importance. Water scarcity is also of grave concern across China, particularly in large cities and in the arid North. As urban areas draw more water resources away from poorer, rural ones through massive water diversion projects, sewered sanitation solutions that depend on fresh water for flushing could become less feasible.
- Using the methodologies outlined below:
  - The annual upside market for the reinvented toilet (RT) is estimated at ~523,000 units in 2030. Of this, the residential market is expected to make up ~97% of the total, comprised of roughly 438,000 SURTs and 67,000 MURT. China represents a relatively large percentage (~20%) of the total annual market for the RT. For comparison, the Indian market is estimated at 328,000 units annually.1,2
  - The omni ingestor (OI) market spans both urban and rural markets and is estimated at 64,000 units, representing approximately 25 to 35% of the total global market.
  - The potential market for the omni processor (OP) is large, encompassing 98% of China's urban 1.657 cities and between 10 and 20% of the total global market for fecal sludge treatment plants (FSTPs).3 This reflects China's continued reliance on septic tanks for primary treatment and the need to treat fecal sludge (FS) from populations that are both fully reliant and partially reliant on OSS. An additional 628 cities could have a need for advanced biosolids treatment, expanding the market even further.
  - RT products may benefit from limited government subsidies in rural areas, stimulating adoption. To date, government has invested little in FSM but has a tradition of investing in sectors that align with their political priorities, including spending an estimated $6 billion per year on wastewater treatment between 2011 and 2015.4 The country is expected to invest an additional $46 billion in sewer expansion between 2016 and 2020.3

Population and Housing Trends

China is home to 1.4 billion people, 56% residing in urban areas (2015). The country's annual population growth rate is a low 0.5% although the country is experiencing rapid urbanization as people move in search of better employment opportunities. About 67% of China's population is expected to reside in urban areas by 2030.5

High population density characterizes China's urban areas with housing stock dominated by multi-family dwellings (88% of urban HHs in 2007),6 whereas in rural China, families typically live in small, wooden dwellings (estimated 70% of rural HHs).7 Expectations of migration to small and medium-sized cities has driven an overproduction in residential construction. Over the past 5 years, China has built more than 10 million new apartment units annually, surpassing annual demand for about 8 million units, although official government documents place production at about 8 million.8 Although this has led to the proliferation of hundreds of "ghost cities," this trend is expected to continue. Based on a report by China's central planning agency, city development plans could house 3.4 billion people by 2030, despite this significantly exceeding current projected growth rates.9

Sewage Coverage in China

China's approach to sanitation has strongly favored the growth of underground sewers with aggressive city-level targets being set every 5 years through the central government's Five Year Plans (FYPs). Based on government documents, China exceeded some of its 2015 sewage treatment goals of 100%, 85%, 70%, and 30% in 36 select cities, municipalities, counties, and towns, respectively, while falling short on others. Regardless, FYP13 was issued

continued on page 2
Policy Landscape

China is home to 20% of the world’s population but holds only 6% of the world’s water resources, making water central to the country’s economic growth and political priorities. To curb pollution, the central government continues to expand its goals and reach by striving towards higher sewerage coverage rates and enacting increasingly stringent discharge standards. A new national strategy to reduce water pollution was issued in 2015 with the goal of eliminating heavily polluted water basins by 2020 and fully restoring water ecosystems by 2030. With this, FSM is expected to grow in importance.

In China, FS (otherwise referred to as night soil or excrement) is considered a form of municipal solid waste and is regulated by the Ministry of Construction. Standards on FS transport and treatment were first established in the late 1990s and amended in 2008. Policies and guidance documents span the sanitation value chain from onsite storage to treatment.

Based on existing design guidelines, all HHs must first pretreat their sewage in an onsite septic tank or anaerobic tank, regardless of access to sewage treatment. However, some coastal cities such as Shanghai, Hangzhou, and Guangzhou are abandoning septic tank installation in newly built areas.

Fecal Sludge Generation and Collection

An estimated 226 million m$^3$ of FS are accumulated across China each year. FS collection in urban China reached a height of 38 million m$^3$ per year in 2005, and then began to steadily decline at a rate of 6.5% annually as sewage treatment capacity increased (see graph). In 2015, 14.4 million m$^3$ of FS (40,000m$^3$/d) were collected from 126,000 latrines, of which 47% was treated at a WWTP or a centralized FSTP. The remaining 7.6 million m$^3$ is thought to either be land applied for agricultural benefit or indiscriminately dumped, while 212 million m$^3$ may go uncollected.

Funding for the RT

There is evidence to suggest government funding for toilet technologies is likely to come in several forms: central government subsidies for household toilets, regional government purchases of MURTs, and central and regional government purchases of public toilets. For example:

- Prior to 2010, the central government funded $5.7B in sanitation projects in rural areas including biogas reactors and sanitary toilets for ~187 million HHs.
- In Youngkang Village in Central Jiangsu, households received ~$129 from the government to renovate their toilets against a total average cost of $483, with homeowners expected to pay the difference. The central government offers subsidies ranging from $22-74 for building new toilets, with amounts varying by region.

However, only limited evidence suggests that China is moving away from its use of septic tanks for preliminary treatment; therefore, FS collection is expected to continue as HH’s transition from being fully reliant to partially reliant on OSS.

Reliance on OSS

A toilet revolution is underway in China. Today, 75% of rural areas have sanitary toilets, and the government plans to reach 85% coverage by 2020.

Prior to the rapid expansion of sewers in the early 2000s, nearly all HHs relied on a septic tank. Unique to China, these septic tanks are still used as a primary treatment step today, even though most urban HHs are now also connected to sewers (partially reliant populations). In this system, effluent flows to a WWTP for treatment while sludge settles to the bottom of the septic tank and is periodically removed for disposal or treatment.

Despite significant gains in sewage treatment, nearly 728 million Chinese still rely exclusively on OSS today, and 2% of the rural population practices open defecation. With central government targets to reach 100% sewage treatment in municipalities, 95% in prefecture-level cities, and 85% in counties by 2020, this number is expected to decline precipitously into the future.

<table>
<thead>
<tr>
<th>Sanitation coverage estimates(2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban (%)</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Sewer connections</td>
</tr>
<tr>
<td>Other improved</td>
</tr>
<tr>
<td>Other unimproved</td>
</tr>
<tr>
<td>Open defecation</td>
</tr>
</tbody>
</table>

Continued from page 1

in 2016, setting even higher goals and emphasizing their continued commitment to this strategy.

An estimated 48% of China’s population had access to sewers in 2015, with substantially higher underground sewer connectivity observed in urban populations (79%) than rural ones (9%). 46 billion m$^3$ of wastewater are collected each year. A total of 92% is treated, and 88% is processed in a centralized wastewater treatment plant (WWTP). It is likely that the remaining 4% of wastewater collected is managed in small-scale WWTPs.
Probable buyers of SUFTs will be homeowners, whereas MURT will likely be purchased by builders/building owners in urban areas and regional/local government in rural areas. It is likely that OPs will be purchased by regional/local governments as well.

<table>
<thead>
<tr>
<th>Likely Buyers of Sanitation Products</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT - SURT</td>
<td>Homeowner (potential govt subsidy for rural HHs)</td>
<td></td>
</tr>
<tr>
<td>RT - MURT</td>
<td>Builder/Building Owner</td>
<td>Regional or local government</td>
</tr>
<tr>
<td>RT – MURT (Public Toilets)</td>
<td>National government</td>
<td></td>
</tr>
<tr>
<td>OI</td>
<td>Unknown – local government or private operator</td>
<td>Regional or local government</td>
</tr>
</tbody>
</table>

**Funding for FSM**

In recent years, spending on wastewater management has favored the expansion of underground sewers, increasing treatment capacity and effluent reuse. Spending on wastewater treatment totaled $60 billion between 2011 and 2015, with more than half of the funds coming from private sources. Annual government spending on FSM is estimated at $360 million (2014), representing only 5% of spending on total expenditures on environmental sanitation services, which also includes solid waste management. Spending is growing at a compounded annual growth rate (CAGR) of 8.7%, although future allocations to FSM are unknown. By comparison, utility spending is growing at a rate of 3% per year, indicating that further rate increases may be required to cover costs.

Historically, urban water and wastewater utilities in China have operated at a deficit or very low profit margin. HHs pay municipal utilities a combined water and wastewater fee-in-2012, the average wastewater charge was $0.13/m³. However, tariffs are on the rise across China as the government tries to curtail consumption, conserve water resources, and enact a polluter pays system. To do so, in 2015, government established a floor of ~0.13/m³, equating to an average $58/HH/year. It appears unlikely that per unit wastewater charges are inclusive of septic tank desludging and FS treatment, indicating that further rate increases may be required to improve FSM services.

In rural communities, village-level governments are responsible for ongoing operating costs, however the taxation of village inhabitants’ incomes is prohibited, often resulting in a lack of funding. There is no direct evidence of rural HHs paying for sewage treatment, although user fees for solid waste and water services suggest it is possible. For example, the World Bank successfully issued large rural water infrastructure loans to regional governments between 1985 and 2005 totaling $628 million, 75% of which was repaid through HH user fees. HHs were charged $0.30/m³, equivalent to ~3.6% of their total annual income, and payment compliance was usually over 90% due to a variety of incentive structures. Although willingness to pay (WTP) data for sanitation projects is unknown, WTP for solid waste services also offers a useful basis for comparison. According to a 2011 study of a poor county in Yunnan Province, the mean WTP was 1% of a HHs total annual income for solid waste management services, or $16/year. The poorest HHs were willing to pay 5%, highlighting the likely greater impact of solid waste on their daily lives.

**Incumbent Solutions**

Decentralized sewage treatment is the most popular method of treating sewage in rural China, and 97% of all decentralized treatment systems include a septic tank. In a study of 62 treatment systems, the most common combination of technologies was a septic tank followed by either a membrane bioreactor or an activated sludge process. The cost to establish and maintain this type of multi-family system ranges from $59 to $586/m³ of daily installed capacity and operating costs are $0.10/m³.

For those HHs that are fully reliant on OSS, whether in rural or urban areas, pit latrines are the predominant type of system in use, suggesting that underground sewer expansion has favored septic tank users. Because of limited water resources and a demand for fertilizer products, composting toilets are used 2.6% of the total population, although their adoption has had limited success in urban areas. For example, “eco-toilets” were installed in 832 apartments in Dongsheng, but they failed because of inefficient piping and ventilation and lack of user experience. A reported 15.4 million rural HHs are also using small-scale biogas digesters. The digesters have been positively received by HHs because of their cost saving benefits: fertilizer for growing crops, electricity for lighting, gas for stovetop cooking, and a reduction in medical costs attributed to diarrheal disease.

**China’s Toilet Revolution**

In January 2015, China’s National Tourist Administration pledged to build or renovate 100,000 public toilets in tourist sites around the country by 2020. The program is progressing ahead of schedule. In April 2017, the central government announced that it had exceeded its new toilet target for Beijing, having already installed 36,000 units, with only 10,000 renovations to go. Total investment in the program has exceeded $3 billion, with funding coming from the central and local governments.

In 2015, there were 167,000 public toilets across China, with numbers expected to grow to 370,000 by 2030. Public tourism sites are believed to be early adopters of MURT technologies given the current focus of government funding and their high visibility.
Potential Market for the Omni Ingestor (OI)

Vacuum collection occurs in populations that are fully reliant and partially reliant on OSS. Based on FS volumes collected in 2015 (see above), the current addressable market for a typical 5m³ truck is approximately 3,000 units. However, the potential market, assuming all FS is collected is about 64,000 units. The total market size is expected to decrease slightly by 2025 despite a shift towards underground sewers, as those HHs continue desludging their onsite septic tanks.

<table>
<thead>
<tr>
<th>Total Potential Market for the OI (Thousands of Units)</th>
<th>2017</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>64</td>
<td>60</td>
</tr>
</tbody>
</table>

Market for the Omni Processor

Because of China’s reliance on septic tanks, 98% of China’s 1,657 urban cities make up the potential market for the OP.¹⁷ 1,009 of these cities generate between 100 and 500 m³ of FS per day, and an additional 221 cities generate between 500 and 1,000 m³ per day. Taken together, these cities represent 76% of the total FS generated by urban areas nationwide.

A total of 628 cities have WWTPs that produce biosolids. Of those, 70% or 438 cities produce between 1 and 15 dry tons of solids each day. The largest share of total biosolids production comes from 37 cities that generate between 100 and 500 dry tons per day followed by 4 mega-cities (Shanghai, Beijing, Guangzhou, and Shenzhen) at 31% of total nationwide production. Current biosolids management practices include incineration, anaerobic digestion, lime stabilization, and landfill disposal, although dewatering plus landfill disposal is the predominant method used.²⁸ According to government regulations, FS can only make up 10% of a landfill’s incoming feedstock, which may create incentive for alternative use, especially as sewage treatment rates continue to grow.

Potential Market for the Reinvented Toilet (RT)

The total upside annual market opportunity for the RT is projected to reach ~530,000 units by 2030. The market is dominated by demand from residential customer segments, with SURT demand exceeding MURT demand by 6X. This is partially attributed to the larger number of users per MURT, but also because of high UGS coverage rates in urban, apartment-prevalent areas. With the large volume of new apartment units under construction in China, the new construction market for MURTs and SURTs is expected to reach 42,000 and 19,000, respectively.²

<table>
<thead>
<tr>
<th>Total Market for the RT²</th>
<th>SURT</th>
<th>MURT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>1,997</td>
<td>102</td>
</tr>
<tr>
<td>2025</td>
<td>438,248</td>
<td>67,894</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>103</td>
<td>85,686</td>
</tr>
</tbody>
</table>

Sanitation Technology Platform

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Methodology

Market size estimates were calculated using the following methodologies. Baseline data was collected from a mix of secondary and primary sources, and in some cases, based on assumptions provided by local experts.

Market Sizing for RT:
- Analysis offers upside estimate. Model takes a snapshot of annual revenue and sales potential in 2030, and assumes RT to have achieved steady state market dynamics.
- RT uptake rate depends on both toilet type and past improvement in sanitation of country.
- Adoption of SURT vs. MURT depends on construction type (e.g., standalone houses use SURT, apartments use MURT). Those cities alone are not believed to be a potential market for the OP.
- Market is segmented across toilet (unimproved, latrine, septic, sewer) and construction types (new versus existing construction). Residential markets = Number of households x expected RT uptake; Non-residential market = total square footage x expected RT uptake.

Market Sizing for OI:
- Using data from the National Bureau of Statistics, populations were segmented by fully reliant (those that rely exclusively on OSS) and partially reliant (those that have a septic tank and are also connected to a sewer) populations.
- Using technical standards for septic tanks in China, STeP estimated the total daily volume of FS accumulated nationwide. It was assumed that trucks service, on average 2.7 HHs / day, and operate 312 days / year. Based on a cursory search of desludging vehicles for sale in the Chinese marketplace, vehicle size is assumed to be 5 m³.

Market Sizing for OP:
- Using city-level sewage treatment rates from the National Bureau of Statistics, STeP estimated the daily volume of FS accumulated by city, segmenting cities by accumulation rate. Note: It is recognized that sewage treatment rates are not synonymous with sewerage coverage rates, however this represents the best available city-level data and is believed to reflect the percentage of sewage treated of the total generated, rather than the percentage treated of that collected.
- Daily dry biosolids production rates were also sourced from the National Bureau of Statistics. City-level data on sludge management is not known, therefore, it is assumed that 100% of the biosolids generated are available for processing at an OP.