# resilience.io

## GAMA WASH use cases

the ecological sequestration trust

# resilience.io GAMA WASH use cases

# WASH Use case results and discussions

## Introduction

The resilience.io Water and Sanitation prototype model has been developed by Imperial College London, The Institute of Integrated Economic Research and The Ecological Sequestration Trust together with expert inputs from the GAMA Technical Group. This prototype has been funded by the Department for International Development and developed as a major part of the Future Cities Africa pilot project managed by the Cities Alliance.

As part of the development of the resilience.io prototype model for the Water and Sanitation (WASH) sector in GAMA under the DfID Future Cities Africa project, three use cases were developed with key stakeholders in GAMA which relate to particular challenges at different planning levels. The use cases demonstrate how people could use the resilience.io prototype tool to plan, manage or improve the water, sanitation and hygiene systems. The use-cases demonstrate the functionality of the prototype to local stakeholders, and help explain its benefits. In this report three use cases are provided, including their main topics of use, the results as modelled by resilience.io, and the interpretation of use case model results, thereby demonstrating the potential usefulness of utilizing the resilience.io platform in WASH planning.

The team are available to continue to work with people and institutions in Ghana to further develop these, and other investigations using the resilience.io prototype to support strategic development. Please visit resilience.io or email stephen.passmore@ecosequestrust.org for more information.

# resilience.io Use Case 1: Envisioning outcomes of ongoing WASH projects and steps to meet macro-level WASH targets

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| **Created:** | May 2016 |
| **Authors:** | Rembrandt Koppelaar (IIER), Xiaonan Wang (ICL), Koen van Dam (ICL), Harry Triantafyllidis (ICL), Hannes Kunz (IIER), Nilay Shah (ICL) |

## 1.1 Overview

The capital city of Ghana and its neighbouring administrative districts form the Greater Accra Metropolitan Area (GAMA). A rapidly growing metropolitan region where efforts to improve the water, sanitation, and hygiene (WASH) situation have yielded mixed results. Household access to piped water grew by 81% to 83% from 2000 to 2010 and access to public and private improved toilet facilities increased from 58% to 81% (Twum-Baah et al. 2005; Bentsi-Enchill et al. 2013). However, the percentage of total wastewater treated, including human excreta, declined from around 10% to near zero between 2000 and 2010, whilst the population of GAMA grew from 3 to 4 million people.

The first use case serves to demonstrate how resilience.io can provide knowledge support for the implementation of macro-planning targets for GAMA to improve the WASH situation from the 2010 level, such as those outlined in the Sustainable Development Goals, as well as the Ghana Water Sector Strategic Development Plan (WSSDP) for 2012 to 2025, as developed by the Ministry for Water Resources, Works and Housing. The aim is to understand what combined projects and changes in infrastructure are required so as to deliver a set of WASH targets. Also taking into account the extent to which currently ongoing WASH projects once completed will be able to meet those targets.

The focus lies on making it easier and more effective to investigate potential technological infrastructure interventions and their costs for GAMA. The geographic boundary definition of GAMA as a city region used in the use case was defined by local stakeholders using the Metropolitan and Municipal District Assembly (MMDA) structures in the country (GAMA FCA Ref. Group 2015). The definition includes 15 districts, with the Accra and Tema Metropolitan districts as the most populous and with the majority of economic activity. The calculations are carried out at both the individual MMDA level, and aggregated to GAMA in the results, in line with and in support of the development of District Medium Term Development Plans (DMTDP).

Changes within GAMA at project level have been successful for potable water provisioning in recent years. The city has seen large expansions of potable water treatment at the Kpone site north of the city-region of several hundred thousand cubic metres per day, as well as the addition of a 60,000 $m^3$ per day desalination plant. In terms of waste-water treatment the situation has deteriorated, however, as the two large scale treatment plants had broken down in AMA and TEMA districts. These include the Jamestown treatment plant with 16,000 $m^3$ per day capacity which broke down in 2004 and has not operated since, and the TEMA community 3 lagoon based treatment plant with 20,000 $m^3$ per day capacity has been out of use since 2000. Nearly all waste-water thereby ends up directly or via collection in the environment untreated. The main change since has been the addition of a lagoon based treatment plant with a capacity of 6400 $m^3$ per day at the University of Ghana Legon. Also efforts are underway to rehabilitate the Jamestown treatment plant. The main challenges for waste-water relate to overall lack of financing of projects, and the limited ability to maintain existing treatment plants.

The use case is described in section 1.2. The calculation functionality and scenarios provided by resilience.io to support policy inputs is described in section 1.3. The results of the use case scenario runs are visually provided in section 1.4. Finally, conclusions from the use case are summarised in section 1.5 below.

## 1.2 Use Case Description

The framework for planning of water and sanitation in Ghana at a national level is outlined in the Water Sector Strategic Development Plan (WSSDP) for 2012 to 2025 as developed by the Ministry for Water Resources, Works and Housing. The specific urban objectives in the plan are to increase urban water and sanitation coverage both to 100% in 2025. To reach these targets the plan outlines detailed country-wide financial needs and mechanisms, and also discusses aims for institutional coordination and strengthening.

The use case serves to translate such national targets, to what efforts would be required to reach these targets at the level of the GAMA city-region. In this context the use case demonstrates the following functionality for users:

- The automated calculation of the lowest investment and operational costs for GAMA, based on the infrastructure changes required to meet macro-level water and sanitation targets (e.g. those set in the national and local planning frameworks and international agreements). The estimates start from the baseline situation in 2010 and from there take a five year time-step, and are inclusive of WASH projects which are already on the way, such as the Accra Sewerage Improvement Projects.

- The additional calculation of how meeting the WASH targets will change required inputs into the water and sanitation sector, including electricity use and job needs. As well as how it changes outputs of greenhouse gas emissions of the sector.
- The ability to add potential user chosen new projects including treatment facilities in a particular MMDA, and pipelines between MMDAs, based on the technology choice, the treatment capacity of the facility, and year of project completion. The model then calculate these project's impacts on key indicators and overall cost estimates, in addition to model selected lowest cost interventions.
- The possibility to set a limit to available budgets and evaluate given this limitation what target level could be met in terms of water and sanitation macro-level targets, such as reaching 90% instead of 100% improved water sources.

The outcomes are calculated on the basis of a substantial number of input values. First, the inputs which describe the baseline 2010 situation in GAMA including population with a number of key socio-economic characteristics, existing infrastructure and access thereto, and the technicalities of available WASH technologies. Second, a number of specific data inputs which describe the parameter settings of a scenario, such as restrictions to expansion of pipelines, additional technology facilities set by the user, and budget constraints or otherwise.

The data inputs are described in the following section on scenarios. In total over 50 such settings can be altered within a given scenario. The calculation process and scenario settings are described in more detail in a resilience.io report explaining the technical mechanisms of the model, which is available upon request (reference).

### 1.3 Scenarios for first use case

There are many approaches to reach national targets in terms of types of policies and infrastructure. A total of four scenarios are calculated within the use case to demonstrate how national targets can be met in different ways and the implications thereof. These are all based on a baseline scenario which calculates how water and sanitation will develop from 2010 to 2030, with no additional change beyond on-going projects.

The four scenarios can be summarised as:

- **Baseline scenario**, so as to assess effects of current WASH projects and policies, based on the initial set of treatment facilities and infrastructure as established in 2010 as the starting point. On top of these on-going projects are added which have been built since 2010 or are currently in the pipeline of being built. Only projects which are both funded and have been approved by the government of Ghana and local authorities are included.
- **City-wide systems scenario**, so as to assess requirements to reach national 2025 WASH targets with a focused on city-wide systems. The model incorporates user selected infrastructure in the form of large scale conventional waste-water treatment in the two populous centres of the city-region AMA and TEMA, and similarly large scale conventional treatment expansion at the Kpong site on the Volta River.
- **City-wide systems leakage reduction scenario**, similar to the city-wide systems scenario except that leakage rates from water and waste-water pipe systems are set to 17% from the original 27% in the system from 2020 onwards, so as to ascertain cost impacts of leakage reduction.
- **Decentralised districts scenario**, so as to assess requirements to reach national 2025 WASH targets with a focus on district level infrastructure. The model incorporates significant constraints to the expansion of pipelines for water and wastewater and otherwise gives free selection over technologies and infrastructures.

- **SDG targets scenario**, so as to assess requirements to reach 2030 targets for WASH in the Sustainable Development Goals. The model incorporates the targets for 2030 and otherwise gives free selection over both technologies and pipeline infrastructures.
- **SDG targets leakage reduction scenario**, similar to the city-wide systems scenario except that leakage rates from water and waste-water pipe systems are set to 17% from the original 27% in the system from 2020 onwards, so as to ascertain cost impacts of leakage reduction.

In the next four subsections the baseline inputs and assumptions for these six scenarios are provided in detail prior to a summary of the results in section 1.4.

### 1.3.1 Baseline scenario

*Table 1.1 – Population socio-economic scenario parameters used to initialize the model*[1]

| District / Parameter | GAMA average | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Crude Birth Rates** | n/a | 26.0 | 19.7 | 23.5 | 27.2 | 31.8 | 26.3 | 25.1 | 24.4 | 18.9 | 22.5 | 21.9 | 21.0 | 27.5 | 25.4 | 23.2 |
| **Crude Death Rates** | n/a | 3.4 | 4.4 | 3.9 | 3.1 | 4.2 | 3.3 | 3.4 | 4.0 | 4.4 | 3.5 | 3.6 | 4.4 | 9.5 | 2.5 | 5.2 |
| **Ageing rate 0-14 to 15+** | 0.06 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Immigration rate 0-14** | n/a | 0.046 | 0.023 | 0.027 | 0.036 | 0.036 | 0.038 | 0.034 | 0.039 | 0.020 | 0.035 | 0.021 | 0.026 | 0.013 | 0.043 | 0.019 |
| **Immigration rate 15+** | n/a | 0.046 | 0.023 | 0.027 | 0.036 | 0.036 | 0.038 | 0.034 | 0.039 | 0.020 | 0.035 | 0.021 | 0.026 | 0.013 | 0.043 | 0.019 |

[1] Accra Metropolitan Assembly (AMA), Adentan Muncipal Assembly (ADMA), Akwapim South Municipal Assembly (ASMA), Ashaiman Municipal Assembly (ASHMA), Awutu-Senya-East (ASEMA), Ga Central Assembly (GCMA), Ga East Municipal Assembly (GEMA), Ga West Municipal Assembly (GWMA), Kpone Katamanso Municipal Assembly (KKMA), La Dade-Kotopon Municipal Assembly (LADMA), La Nkwantanang Madina Municipal (LANKA), Ledzokuku-Krowor Municipal Assembly (LEKMA), Nsawam-Adoagyiri Municipal Assembly (NAMA), Tema Metropolitan assembly (TEMA).

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Emigration rate 0-14** | 0.0122 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Emigration rate 15+** | 0.0122 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Employment change Rate 15 plus** | 0.05 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Employment decrease rate 0 to 14** | 0.05 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Income low to medium** | 0.003 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Income medium to high** | 0.003 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

*Table 1.2 – Water and Sanitation Demand scenario parameters used to initialize the model*

| **Scale**<br>**Parameter** | **All** | **Low income** | **Medium income** | **High income** |
|---|---|---|---|---|
| **Water use per capita** | n/a | 0.73 (equivalent to 51-65 litres/capita) | 1.00 (equivalent to 70-90 litres/capita) | 1.56 (equivalent to 109-140 litres/capita) |
| **Pipe Drinking Use** | 63.0% | n/a | n/a | n/a |
| **Sachet Drinking Use** | 28.5% | n/a | n/a | n/a |
| **Scale** | **Female** | **Male** | **Child Female** | **Child Male** |
| **Residential water parameter** | 1.3 | 1.0 | 0.9 | 0.7 |
| **Drinking water parameter** | 1.0 | 1.2 | 0.8 | 0.8 |
| **Daily drinking water use (litres)** | 3.0 | 4.0 | 2.1 | 2.1 |
| **Rationing demand reduction parameter** | 0.65 | 0.65 | 0.65 | 0.65 |

| | | | | |
|---|---|---|---|---|
| **Unimproved demand reduction parameter** | 0.78 | 0.78 | 0.78 | 0.78 |
| **Scale** | **n/a** | **Commercial** | **Institutional** | **Industrial** |
| **Company water use parameter (m3/day)** | n/a | 14.5 | 1.6 | 100 |

*Table 1.3 – Water and Sanitation Supply scenario parameters used to initialize the model*

| **Year run** / **Parameter** | **2010** | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|
| **Water demands met %** | TBD | TBD | TBD | TBD | TBD |
| **Wastewater demands met %** | TBD | TBD | TBD | TBD | TBD |
| **Minimum production for pre-allocated (existing) infrastructure** | 50% | 50% | 50% | 50% | 50% |
| **Leaks in pipe network** | 27% | 27% | 27% | 27% | 27% |
| **Budget maximum per 5 years (USD)** | 500 million | 500 million | 500 million | 500 million | 500 million |
| **Cost of electricity (USD per kWh)** | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **Cost of labour (USD per hour)** | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| **Cost of pipeline construction (USD per km)** | 235,000 | 235,000 | 235,000 | 235,000 | 235,000 |
| **Cost of pipeline operation (USD per m)** | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

*Table 1.4 – Operational water treatment infrastructure capacity per district in 2010 in $m^3$ per day used to initialize of the model*

| District / Technology Capacity | Source water treatment plant | Borehole source water | Protected well, spring or rainwater collection | Unimproved sources (wells, springs, waterbodies) | Sachet water producers | Bottling water producers | Tanker / vendor provision |
|---|---|---|---|---|---|---|---|
| **ACCRA_METROPOLITAN** | 0 | 3600 | 1776 | 1300 | 464 | 23 | 2435 |
| **ADENTA** | 0 | 2580 | 258 | 150 | 41 | 0 | 5585 |
| **AKWAPIM_SOUTH** | 0 | 3180 | 492 | 1400 | 5 | 0 | 125 |
| **ASHAIMAN** | 0 | 4380 | 168 | 150 | 10 | 0 | 710 |
| **AWUTU_SENYA_EAST** | 0 | 9870 | 1812 | 1150 | 38 | 0 | 2090 |
| **GA_CENTRAL** | 0 | 4620 | 1308 | 750 | 49 | 0 | 1985 |
| **GA_EAST** | 0 | 10,200 | 1956 | 550 | 79 | 0 | 2940 |
| **GA_SOUTH** | 0 | 36,840 | 1386 | 3350 | 90 | 0 | 3100 |
| **GA_WEST** | 229,500 | 19,260 | 4104 | 2150 | 138 | 0 | 3690 |
| **KPONE_KATAMANSO** | 0 | 8730 | 84 | 250 | 10 | 0 | 2720 |
| **LA_DADE_KOTOPON** | 0 | 180 | 78 | 100 | 44 | 0 | 925 |
| **LA_NKWANTANANG_MADINA** | 0 | 6270 | 1998 | 300 | 69 | 0 | 5170 |
| **LEDZOKUKU_KROWOR** | 0 | 300 | 462 | 250 | 51 | 0 | 4395 |
| **NSAWAM_ADOAGYIRI** | 0 | 9540 | 1158 | 1150 | 10 | 0 | 30 |
| **TEMA_METROPOLITAN** | 0 | 7200 | 132 | 300 | 18 | 0 | 305 |
| **VOLTA_RIVER (KPONE)** | 204,000 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.5 – Operational waste-water treatment infrastructure capacity per district in 2010 in $m^3$ per day used to initialize of the model*

| District / Technology Capacity | Conventional large-scale wastewater treatment | Small activated sludge systems | Faecal sludge polymer separation and drying | Aerated Lagoon systems | Waste stabilisation ponds | Small-scale anaerobic biogas treatment | Small-scale aerobic treatment plant |
|---|---|---|---|---|---|---|---|
| ACCRA_METROPOLITAN | 0 | 120 | 0 | 0 | 0 | 11 | 0 |
| ADENTA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AKWAPIM_SOUTH | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| ASHAIMAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AWUTU_SENYA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_CENTRAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_WEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| KPONE_KATAMANSO | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LA_DADE_KOTOPON | 0 | 4 | 0 | 0 | 0 | 0 | 250 |
| LA_NKWANTANANG_MADINA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LEDZOKUKU_KROWOR | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| NSAWAM_ADOAGYIRI | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| TEMA_METROPOLITAN | 0 | 375 | 0 | 0 | 0 | 0 | 0 |

The additional on-going projects since 2010 are incorporated in the baseline scenario as added in the 2015 and 2020 time years and utilisable in forward years 2025 and 2030 as well. The capacity representation of incorporated projects can be found in table 1.6 amd 1/7 below and include the following:

- **Accra Sewerage Improvement Project (ASIP)**
- **GH-Gama water and Sanitation Project (GH-GAMA)**
- **DANIDA Lavender Hill Sludge Treatment**
- **Slamson Ghana Korle Lagoon cesspit treatment**.
- **Jamestown/Korle Lagoon sewerage plant rehabilitation**
- **Mudor Faecal Treatment plant**

Also a number of already completed projects are incorporated in the on-going set of projects, as these were finished after 2010, and include:

- **Teshie-Nungua Desalination plant**
- **Kpong China Gezhouba expansion**
- **Kpong Tahal expansion**

*Table 1.6 – Additional water treatment infrastructure capacity per district by 2020 in $m^3$ per day from on-going projects*

| District / Technology Capacity | Source water treatment plant | Desalination treatment | Borehole source water | Protected well, spring or rainwater collection | Unimproved sources (wells, springs, waterbodies) | Sachet water producers | Bottling water producers | Tanker / vendor provision |
|---|---|---|---|---|---|---|---|---|
| ACCRA_METROPOLITAN | 0 | 0 | 8569 | 0 | 0 | 0 | 0 | 0 |
| ADENTA | 0 | 0 | 410 | 0 | 0 | 0 | 0 | 0 |
| AKWAPIM_SOUTH | 0 | 0 | 205 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ASHAIMAN** | 0 | 0 | 984 | 0 | 0 | 0 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 0 | 0 | 574 | 0 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 0 | 615 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 0 | 779 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 0 | 2132 | 0 | 0 | 0 | 0 | 0 |
| **GA_WEST** | 0 | 0 | 1148 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 574 | 0 | 0 | 0 | 0 | 0 |
| **LA_DADE_KOTOPON** | 0 | 0 | 984 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 0 | 0 | 615 | 0 | 0 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 60,000 | 1189 | 0 | 0 | 0 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 0 | 0 | 451 | 0 | 0 | 0 | 0 | 0 |
| **TEMA_METROPOLITAN** | 0 | 0 | 1517 | 0 | 0 | 0 | 0 | 0 |
| **VOLTA_RIVER (KPONE)** | 396,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.7 – Additional waste-water treatment infrastructure capacity per district by 2020 in $m^3$ per day from on-going projects*

| District / Technology Capacity | Conventional large-scale wastewater treatment | UASB faecal sludge treatment | Small activated sludge systems | Faecal sludge polymer separation and drying | Aerated Lagoon systems | Waste stabilisation ponds | Small-scale anaerobic biogas treatment | Small-scale aerobic treatment plant |
|---|---|---|---|---|---|---|---|---|
| ACCRA_METROPOLITAN | 16,120 | 2400 | 0 | 3800 | 0 | 12538 | 0 | 0 |
| ADENTA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AKWAPIM_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ASHAIMAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AWUTU_SENYA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_CENTRAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_WEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| KPONE_KATAMANSO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LA_DADE_KOTOPON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LA_NKWANTANANG_MADINA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LEDZOKUKU_KROWOR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NSAWAM_ADOAGYIRI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TEMA_METROPOLITAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.8 – Initial district to district water connections in 2010 from/to with a capacity of 1800 m3 per hour*

| District \ District | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA | VOLTA_RIVER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ADENTA** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ACCRA_METROPOLITAN** | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ASHAIMAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **GA_WEST** | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **LA_DADE_KOTOPON** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TEMA_METROPOLITAN** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AKWAPIM_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **VOLTA_RIVER** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.9 – Initial district to district waste-water connections in 2010 from/to with a capacity of 1800 m3 per hour*

| District / District | AMA | ADMA | ASMA | ASHMA | ASEMA | GCMA | GEMA | GSMA | GWMA | KKMA | LADMA | LANKA | LEKMA | NAMA | TMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ACCRA_METROPOLITAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ADENTA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AKWAPIM_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ASHAIMAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_WEST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LA_DADE_KOTOPON** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TEMA_METROPOLITAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 1.3.2 City-wide systems scenarios

The scenario forces the expansion of large scale conventional water and wastewater treatment systems. The following additional expansions are user selected in the technology capacity matrix as additional infrastructure:

- Expansion of conventional water treatment at the Volta-River site with an additional 200,000 m3/day. The expansion value is equivalent to the Asutuare expansion project that is in the planning phase that aims to expand capacity from the Volta River to Tema-Accra.
- Construction of conventional waste-water treatment at the Accra Metropolitan with completion by 2025 on top of on-going projects. The user selected capacity is set at 190,000 $m^3$/day
- Construction of conventional waste-water treatment in the TEMA metropolitan district with completion by 2020. The user selected capacity is set at 76,000 $m^3$/day

In the scenario additional baseline of reduction in unimproved sources as per table1.10x below is implemented. Also all pipeline collections are made allowable from 2020 onwards for both water and waste-water treatment as detailed in tables 1.11 and 1.12 below. Beyond these changes also the pipe leakage input parameters are adjusted between the original city-wide systems scenario, and the leakage reduction version. In these scenarios from 2020 onwards the pipe leakage is set from 27% to 17%, assuming a large effort to improve pipe efficiency within GAMA.

*Table 1.10 – Development of unimproved water sources from 2015 to 2030*

| Technology Capacity | Unimproved other sources | | | | Tanker/Vendor Supplies | | | |
|---|---|---|---|---|---|---|---|---|
| **District / Year** | 2015 | 2020 | 2025 | 2030 | 2015 | 2020 | 2025 | 2030 |
| **ACCRA_METROPOLITAN** | 1300 | 650 | 0 | 0 | 2435 | 1218 | 0 | 0 |
| **ADENTA** | 150 | 75 | 0 | 0 | 5585 | 2793 | 0 | 0 |
| **AKWAPIM_SOUTH** | 1400 | 700 | 0 | 0 | 125 | 63 | 0 | 0 |
| **ASHAIMAN** | 150 | 75 | 0 | 0 | 710 | 355 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 1150 | 575 | 0 | 0 | 2090 | 1045 | 0 | 0 |
| **GA_CENTRAL** | 750 | 375 | 0 | 0 | 1985 | 993 | 0 | 0 |
| **GA_EAST** | 550 | 275 | 0 | 0 | 2940 | 1470 | 0 | 0 |
| **GA_SOUTH** | 3350 | 1675 | 0 | 0 | 3100 | 1550 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **GA_WEST** | 2150 | 1075 | 0 | 0 | 3690 | 1845 | 0 | 0 |
| **KPONE_KATAMANSO** | 250 | 125 | 0 | 0 | 2720 | 1360 | 0 | 0 |
| **LA_DADE_KOTOPON** | 100 | 50 | 0 | 0 | 925 | 463 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 300 | 150 | 0 | 0 | 5170 | 2585 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 250 | 125 | 0 | 0 | 4395 | 2198 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 1150 | 575 | 0 | 0 | 30 | 15 | 0 | 0 |
| **TEMA_METROPOLITAN** | 300 | 150 | 0 | 0 | 305 | 153 | 0 | 0 |

*Table 1.11 – Allowable district water connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| | District | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **District** | **ADMA** | **AMA** | **ASHMA** | **GCMA** | **GSMA** | **GWMA** | **GEMA** | **KKMA** | **LADMA** | **LANKMA** | **LEKMA** | **TEMA** | **ASMA** | **ASEMA** | **NAMA** | **VOLTA_RIVER** |
| **ADENTA** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **ACCRA_METROPOLITAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **ASHAIMAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **GA_CENTRAL** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **GA_SOUTH** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **GA_WEST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **GA_EAST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **KPONE_KATAMANSO** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **LA_DADE_KOTOPON** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **LA_NKWANTANANG_MADINA** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **LEDZOKUKU_KROWOR** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **TEMA_METROPOLITAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **AKWAPIM_SOUTH** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **AWUTU_SENYA_EAST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **NSAWAM_ADOAGYIRI** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **VOLTA_RIVER** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.12 – Allowable district wastewater connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| District \ District | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA | VOLTA_RIVER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ADENTA** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **ACCRA_METROPOLITAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **ASHAIMAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **GA_CENTRAL** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **GA_SOUTH** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **GA_WEST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **GA_EAST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **KPONE_KATAMANSO** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **LA_DADE_KOTOPON** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **LA_NKWANTANANG_MADINA** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **LEDZOKUKU_KROWOR** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **TEMA_METROPOLITAN** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **AKWAPIM_SOUTH** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **AWUTU_SENYA_EAST** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **NSAWAM_ADOAGYIRI** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **VOLTA_RIVER** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

### 1.3.3 Decentralised districts scenarios

The scenario serves to examine how 100% improved water and wastewater treatment targets by 2025 can be met by utilising mainly additional decentralised infrastructure. To this end the expansion possibilities for water and waste-water treatment remain capped as detailed in tables 1.14 and 1.15. Also the baseline of unimproved sources except for tanker/vendor supplies are phased out with input data values as per table 1.13 below.

*Table 1.13 – Development of unimproved water sources from 2015 to 2030*

| Technology Capacity | Unimproved other sources | | | | Tanker/Vendor Supplies | | | |
|---|---|---|---|---|---|---|---|---|
| District / Year | 2015 | 2020 | 2025 | 2030 | 2015 | 2020 | 2025 | 2030 |
| ACCRA_METROPOLITAN | 1300 | 650 | 0 | 0 | 2435 | 2435 | 2435 | 2435 |
| ADENTA | 150 | 75 | 0 | 0 | 5585 | 5585 | 5585 | 5585 |
| AKWAPIM_SOUTH | 1400 | 700 | 0 | 0 | 125 | 125 | 125 | 125 |
| ASHAIMAN | 150 | 75 | 0 | 0 | 710 | 710 | 710 | 710 |
| AWUTU_SENYA_EAST | 1150 | 575 | 0 | 0 | 2090 | 2090 | 2090 | 2090 |
| GA_CENTRAL | 750 | 375 | 0 | 0 | 1985 | 1985 | 1985 | 1985 |
| GA_EAST | 550 | 275 | 0 | 0 | 2940 | 2940 | 2940 | 2940 |
| GA_SOUTH | 3350 | 1675 | 0 | 0 | 3100 | 3100 | 3100 | 3100 |
| GA_WEST | 2150 | 1075 | 0 | 0 | 3690 | 3690 | 3690 | 3690 |
| KPONE_KATAMANSO | 250 | 125 | 0 | 0 | 2720 | 2720 | 2720 | 2720 |
| LA_DADE_KOTOPON | 100 | 50 | 0 | 0 | 925 | 925 | 925 | 925 |
| LA_NKWANTANANG_MADINA | 300 | 150 | 0 | 0 | 5170 | 5170 | 5170 | 5170 |
| LEDZOKUKU_KROWOR | 250 | 125 | 0 | 0 | 4395 | 4395 | 4395 | 4395 |
| NSAWAM_ADOAGYIRI | 1150 | 575 | 0 | 0 | 30 | 30 | 30 | 30 |
| TEMA_METROPOLITAN | 300 | 150 | 0 | 0 | 305 | 305 | 305 | 305 |

*Table 1.14 – Allowable district water connections from 2010 onwards from/to with a capacity of 1800 m3 per hour*

| | District | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **District** | **ADMA** | **AMA** | **ASHMA** | **GCMA** | **GSMA** | **GWMA** | **GEMA** | **KKMA** | **LADMA** | **LANKMA** | **LEKMA** | **TEMA** | **ASMA** | **ASEMA** | **NAMA** | **VOLTA_RIVER** |
| **ADENTA** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ACCRA_METROPOLITAN** | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ASHAIMAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **GA_WEST** | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **LA_DADE_KOTOPON** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TEMA_METROPOLITAN** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AKWAPIM_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **VOLTA_RIVER** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.15 – Allowable district waste-water connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| District | District ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ADENTA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ACCRA_METROPOLITAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ASHAIMAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_WEST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LA_DADE_KOTOPON** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TEMA_METROPOLITAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AKWAPIM_SOUTH** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **AWUTU_SENYA_EAST** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NSAWAM_ADOAGYIRI** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 1.4 Results Overview

*Table 1.16 – Results comparison for 1st use case water access plus changes to infrastructure*

| | Year | Baseline | City-wide Systems | City-wide Systems Leakage Reduction | Decentralised districts | Sustainable Development Goals | Sustainable Development Goa Leakage Reductio |
|---|---|---|---|---|---|---|---|
| Improved water % access | 2015 | 70.3% | 70.4% | 83.8% | 70.4% | 70.4% | 83.8% |
| | 2020 | 81.2% | 100% | 100% | 100% | 100% | 100% |
| | 2025 | 75.1% | 100% | 100% | 100% | 100% | 100% |
| | 2030 | 71.9% | 100% | 100% | 100% | 100% | 100% |
| | | | | | | | |
| Total GAMA Population (millions) | 2015 | 4.39 | 4.39 | 4.39 | 4.39 | 4.39 | 4.39 |
| | 2020 | 4.98 | 4.98 | 4.98 | 4.98 | 4.98 | 4.98 |
| | 2025 | 5.68 | 5.68 | 5.68 | 5.68 | 5.68 | 5.68 |
| | 2030 | 6.49 | 6.49 | 6.49 | 6.49 | 6.49 | 6.49 |
| | | | | | | | |
| Total GAMA Improved Potable Water Production (m3 per day) | 2015 | 501,059 | 501,403 | 473,965 | 501,403 | 501,403 | 473,965 |
| | 2020 | 627,063 | 673,505 | 591,422 | 680,685 | 668,957 | 588,365 |
| | 2025 | 652,149 | 789,138 | 688,820 | 939,372 | 759,776 | 673,799 |
| | 2030 | 705,106 | 887,697 | 775,899 | 1,079,031 | 863,600 | 776,169 |
| | | | | | | | |
| Total GAMA Potable Water Demands GROSS of Leaks (m3 per day) | 2015 | 617,141 | 617,141 | 537,315 | 617,141 | 617,141 | 537,316 |
| | 2020 | 710,724 | 673,505 | 591,422 | 680,685 | 668,957 | 588,365 |
| | 2025 | 778,707 | 789,138 | 688,820 | 939,372 | 759,776 | 673,799 |
| | 2030 | 868,899 | 887,697 | 775,899 | 1,079,031 | 863,600 | 776,169 |
| | | | | | | | |
| Total GAMA Potable Water Leakage in pipes (m3 per day) | 2015 | 226,504 | 226,504 | 146,679 | 226,504 | 226,505 | 146,679 |
| | 2020 | 265,757 | 228,539 | 146,456 | 235,719 | 223,991 | 143,399 |
| | 2025 | 269,590 | 280,021 | 179,703 | 430,255 | 250,659 | 164,682 |
| | 2030 | 286,040 | 304,839 | 193,041 | 496,173 | 280,742 | 193,311 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total GAMA Potable Water Demands NET of Leaks (m3 per day)** | 2015 | 390,636 | 390,636 | 390,636 | 390,636 | 390,636 | 390,636 |
| | 2020 | 444,966 | 444,966 | 444,966 | 444,966 | 444,966 | 444,966 |
| | 2025 | 509,117 | 509,117 | 509,117 | 509,117 | 509,117 | 509,117 |
| | 2030 | 582,858 | 582,858 | 582,858 | 582,858 | 582,858 | 582,858 |
| | | | | | | | |
| **Additional district-to district water pipe connection in no.** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 5 | 3 | 0 | 5 | 3 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 1 | 1 | 0 | 1 | 0 |
| | | | | | | | |
| **Additional conventional water treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 357,000 | 204,000 | 306,000 | 331,500 | 178,500 |
| | 2020-2025 | 0 | 204,000 | 178,500 | 382,500 | 153,000 | 153,000 |
| | 2025-2030 | 0 | 153,000 | 127,500 | 229,500 | 178,500 | 178,500 |
| | | | | | | | |
| **Additional desalination plant treatment capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Additional borehole water sourcing capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Additional improved springs, wells, and rainwater collection capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 31,171 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 8,923 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 5,974 | 0 | 0 |

*Table 1.17 – Results comparison for 1st use case waste-water access plus infrastructure change*

| | Year | Baseline | City-wide Systems | City-wide Systems Leakage Reduction | Decentralised districts | Sustainable Development Goals | Sustainable Development Goals leakage Reduction |
|---|---|---|---|---|---|---|---|
| **Improved waste-water % access** | 2015 | 3.8% | 1.5% | 1.5% | 1.5% | 1.5% | 1.5% |
| | 2020 | 7.2% | 52.5% | 51.4% | 52.4% | 50.2% | 50.2% |
| | 2025 | 6.4% | 100% | 100% | 100% | 76.0% | 75.6% |
| | 2030 | 5.6% | 100% | 100% | 100% | 100% | 100% |
| | | | | | | | |
| **Total GAMA Population (millions)** | 2015 | 4.39 | 4.39 | 4.39 | 4.39 | 4.39 | 4.39 |
| | 2020 | 4.98 | 4.98 | 4.98 | 4.98 | 4.98 | 4.98 |
| | 2025 | 5.68 | 5.68 | 5.68 | 5.68 | 5.68 | 5.68 |
| | 2030 | 6.49 | 6.49 | 6.49 | 6.49 | 6.49 | 6.49 |
| | | | | | | | |
| **Total GAMA Waste-water treatment (m3 per day)** | 2015 | 12,067 | 4,605 | 4,605 | 4,605 | 4,605 | 4,605 |
| | 2020 | 26,990 | 196,566 | 188,339 | 186,507 | 179,495 | 179,020 |
| | 2025 | 26,990 | 377,669 | 387,745 | 407,294 | 322,117 | 315,318 |
| | 2030 | 26,990 | 440,909 | 448,719 | 466,287 | 451,907 | 475,438 |
| | | | | | | | |
| **Total GAMA GROSS Waste-water treatment needs (m3 per day)** | 2015 | 312,509 | 312,509 | 312,509 | 312,509 | 312,509 | 312,509 |
| | 2020 | 355,973 | 337,393 | 345,620 | 355,973 | 354,467 | 354,939 |
| | 2025 | 407,293 | 377,669 | 387,745 | 407,294 | 390,646 | 397,445 |
| | 2030 | 466,286 | 440,909 | 448,719 | 466,287 | 451,907 | 475,134 |
| | | | | | | | |
| **Total GAMA Waste-water leakage in pipes (m3 per day)** | 2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020 | 0 | 18,580 | 10,353 | 0 | 1,506 | 1,034 |
| | 2025 | 0 | 29,624 | 19,548 | 0 | 16,647 | 9,848 |
| | 2030 | 0 | 25,377 | 17,567 | 0 | 14,379 | 9,152 |
| | | | | | | | |
| | 2015 | 312,509 | 312,509 | 312,509 | 312,509 | 312,509 | 312,509 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total GAMA Net of leaks Waste-water treatment needs (m3 per day)** | 2020 | 355,973 | 355,973 | 355,973 | 355,973 | 355,973 | 355,973 |
| | 2025 | 407,293 | 407,293 | 407,293 | 407,293 | 407,293 | 407,293 |
| | 2030 | 466,286 | 466,286 | 466,286 | 466,286 | 466,286 | 466,286 |
| | | | | | | | |
| **Additional district-to district waste-water pipe connection in no.** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 5 | 1 | 0 | 1 | 1 |
| | 2020-2025 | 0 | 0 | 5 | 0 | 2 | 2 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Additional Conventional Waste water Treatment capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 96,900 | 96,900 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 161,500 | 161,500 | 0 | 96,900 | 96,900 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Additional Waste Stabilisation Pond capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Additional Aerated Lagoon System Capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 259,625 | 279,650 | 359,550 | 339,575 | 339,575 |
| | 2020-2025 | 0 | 159,800 | 119,850 | 179,775 | 19,975 | 19,975 |
| | 2025-2030 | 0 | 19,975 | 19,975 | 99,875 | 199,750 | 199,750 |
| | | | | | | | |
| **Additional decentralised Activated Sludge System Capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 53,183 | 55,934 | 72,439 | 72,439 | 70,605 |
| | 2020-2025 | 0 | 10,086 | 0 | 95,363 | 35,761 | 37,595 |
| | 2025-2030 | 0 | 44,014 | 36,678 | 18,339 | 76,107 | 69,688 |
| | | | | | | | |
| **Additional decentralised faecal sludge polymer separation drying plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 3,563 | 3,563 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 4,276 | 3,563 |
| | 2025-2030 | 0 | 0 | 713 | 0 | 0 | 0 |
| | | | | | | | |
| | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Additional small scale anaerobic biogas treatment plant capacity (m3 per day)** | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Additional small scale aerobic treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 1.18 – Results comparison for 1st use case costs and revenues – all values in current 2015 dollars and not inflation corrected*

| | Year | Baseline | City-wide Systems | City-wide Systems Leakage Reduction | Decentralised districts | Sustainable Development Goals | Sustainable Development Goals Leakage Reduction |
|---|---|---|---|---|---|---|---|
| **Capital expenditure for on-going and complete infrastructure projects on the ground since 2010 (billion USD per 5 years)** | 2010-2015 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 |
| | 2015-2020 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Capital expenditure for additional water treatment infrastructure per 5 years (billion USD per 5 years)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0.63 | 0.36 | 0.85 | 0.59 | 0.32 |
| | 2020-2025 | 0 | 0.36 | 0.32 | 0.76 | 0.27 | 0.27 |
| | 2025-2030 | 0 | 0.27 | 0.23 | 0.46 | 0.32 | 0.32 |
| **Capital expenditure for additional waste-water treatment infrastructure per 5 years (billion USD per 5 years)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0.42 | 0.42 | 0.13 | 0.13 | 0.13 |
| | 2020-2025 | 0 | 0.58 | 0.56 | 0.19 | 0.38 | 0.38 |
| | 2025-2030 | 0 | 0.07 | 0.06 | 0.03 | 0.16 | 0.15 |
| **Capital expenditure for pipeline expansion for water and waste-water treatment (billion USD per 5 years)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0.23 | 0.1 | 0 | 0.2 | 0.1 |
| | 2020-2025 | 0 | 0 | 0.03 | 0 | 0.03 | 0.01 |
| | 2025-2030 | 0 | 0.03 | 0.01 | 0 | 0.02 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Operational expenditure for infrastructure per year (million USD per year)** | 2015 | 163 | 105 | 73 | 105 | 105 | 73 |
| | 2020 | 204 | 100 | 90 | 108 | 102 | 95 |
| | 2025 | 238 | 136 | 126 | 165 | 124 | 115 |
| | 2030 | 274 | 152 | 141 | 187 | 153 | 145 |
| **Operational expenditure per inhabitant per year (USD per person)** | 2015 | 37.2 | 23.9 | 16.7 | 23.9 | 23.9 | 16.7 |
| | 2020 | 40.9 | 20.0 | 18.2 | 21.7 | 20.5 | 19.1 |
| | 2025 | 41.9 | 24.0 | 22.2 | 29.1 | 21.8 | 20.3 |
| | 2030 | 42.2 | 23.4 | 21.2 | 28.8 | 23.6 | 22.4 |
| **Operational expenditure spent on labour per year (million USD)** | 2015 | 15.4 | 15.1 | 14.8 | 15.1 | 15.0 | 14.8 |
| | 2020 | 17.5 | 17.0 | 14.0 | 20.3 | 15.8 | 13.3 |
| | 2025 | 18.6 | 21.2 | 16.5 | 25.3 | 18.9 | 15.3 |
| | 2030 | 19.1 | 21.6 | 18.8 | 25.4 | 20.4 | 17.1 |
| **Operational expenditure for electricity per year (million USD)** | 2015 | 2.6 | 2.5 | 2.4 | 2.5 | 2.5 | 2.4 |
| | 2020 | 12.5 | 12.5 | 11.6 | 12.7 | 12.5 | 12.1 |
| | 2025 | 12.6 | 18.2 | 17.5 | 20.0 | 15.7 | 15.0 |
| | 2030 | 12.9 | 19.9 | 19.2 | 22.5 | 20.4 | 19.9 |
| **Revenues from water sales via pipe-network (million USD)**[2] | 2015 | 62.5 | 62.6 | 67.9 | 62.5 | 62.5 | 67.9 |
| | 2020 | 74.1 | 86.5 | 86.3 | 85.4 | 85.7 | 84.9 |
| | 2025 | 80.8 | 100.3 | 100.3 | 98.5 | 99.0 | 98.9 |
| | 2030 | 90.0 | 114.9 | 114.9 | 113.3 | 114.9 | 114.9 |
| **Revenues from sewerage from surcharge on water sales via pipe-network (million USD)**[2] | 2015 | 0.8 | 0.3 | 0.4 | 0.3 | 0.3 | 0.4 |
| | 2020 | 1.9 | 15.9 | 15.5 | 15.6 | 15.0 | 14.9 |
| | 2025 | 1.8 | 35.1 | 35.1 | 34.5 | 26.3 | 26.2 |
| | 2030 | 1.8 | 40.2 | 40.2 | 39.6 | 40.2 | 40.2 |

[2] The values assume that all water that is delivered to the end-customer will generate revenue, and that all non-revenue water that does not stem from leaks in the system is accounted for by payments.

*Table 1.19 – Results comparison for 1st use case environment, energy and labour*

| | Year | Baseline | City-wide Systems | City-wide Systems Leakage Reduction | Decentralised districts | Sustainable Development Goals | Sustainable Development Goals Leakage Reduction |
|---|---|---|---|---|---|---|---|
| **Total GHG emissions in tonnes for water and waste-water treatment plus distribution/collection** | 2015 | 4129 | 3395 | 3233 | 3,395 | 3,395 | 3,233 |
| | 2020 | 4578 | 37,962 | 32,996 | 42,021 | 41,571 | 41,277 |
| | 2025 | 4722 | 75,174 | 72,689 | 92,129 | 60,459 | 58,189 |
| | 2030 | 5043 | 84,868 | 84,452 | 107,064 | 94,479 | 93,355 |
| | | | | | | | |
| **GHG emissions in kg per m3 for water and waste-water treatment plus distribution/collection** | 2015 | 8.05 | 6.71 | 6.76 | 6.71 | 6.71 | 6.76 |
| | 2020 | 7.00 | 43.44 | 42.11 | 48.68 | 49.32 | 54.18 |
| | 2025 | 6.95 | 60.65 | 64.38 | 68.39 | 55.70 | 58.63 |
| | 2030 | 6.89 | 60.94 | 65.55 | 69.20 | 69.60 | 74.31 |
| | | | | | | | |
| **Total electricity use in million kWh for water and waste-water treatment plus distribution/collection** | 2015 | 35.72 | 35.14 | 33.16 | 35.14 | 35.14 | 33.16 |
| | 2020 | 173.32 | 174.2 | 161.6 | 175.9 | 173.9 | 168.6 |
| | 2025 | 174.99 | 253.3 | 243.5 | 277.9 | 217.6 | 208.9 |
| | 2030 | 178.89 | 276.1 | 267.5 | 312.6 | 283.1 | 276.1 |
| | | | | | | | |
| **Electricity use in kWh per m3 of water and wastewater treated and distributed/collected** | 2015 | 69.6 | 69.5 | 69.3 | 69.5 | 69.5 | 69.3 |
| | 2020 | 264.9 | 199.3 | 206.2 | 203.8 | 206.3 | 221.3 |
| | 2025 | 257.6 | 204.4 | 215.6 | 206.3 | 200.5 | 210.4 |
| | 2030 | 244.3 | 198.3 | 210.1 | 202.1 | 208.5 | 218.3 |
| | | | | | | | |
| **Total jobs in number for water and waste-water treatment and distribution/collection** | 2015 | 3135 | 3081 | 3013 | 3081 | 3081 | 3013 |
| | 2020 | 3580 | 3465 | 2868 | 4144 | 3220 | 2717 |
| | 2025 | 3798 | 4328 | 3378 | 5170 | 3851 | 3133 |
| | 2030 | 3905 | 4413 | 3832 | 5199 | 4159 | 3486 |
| | | | | | | | |
| | 2015 | 6,394,616 | 6,284,874 | 6,145,854 | 6,284,874 | 6,284,874 | 6,145,854 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Labour hours in number for water and waste-water treatment and distribution/collection in no.** | 2020 | 7,304,236 | 7,067,753 | 5,850,877 | 8,453,921 | 6,567,811 | 5,543,215 |
| | 2025 | 7,748,023 | 8,829,595 | 6,891.098 | 10,547,836 | 7,856,317 | 6,391,393 |
| | 2030 | 7,968,100 | 9,001,755 | 7,816,675 | 10,605,236 | 8,484,555 | 7,111,136 |
| | | | | | | | |
| **Labour hours in no per m3 of water and waste-water treated and distributed/collected** | 2015 | 12.5 | 12.4 | 12.8 | 12.4 | 12.4 | 12.8 |
| | 2020 | 11.2 | 8.1 | 7.5 | 9.8 | 7.8 | 7.3 |
| | 2025 | 11.4 | 7.1 | 6.1 | 7.8 | 7.2 | 6.4 |
| | 2030 | 10.9 | 6.5 | 6.1 | 6.9 | 6.3 | 5.6 |

### 1.4.1 Results District Values for Water Treatment

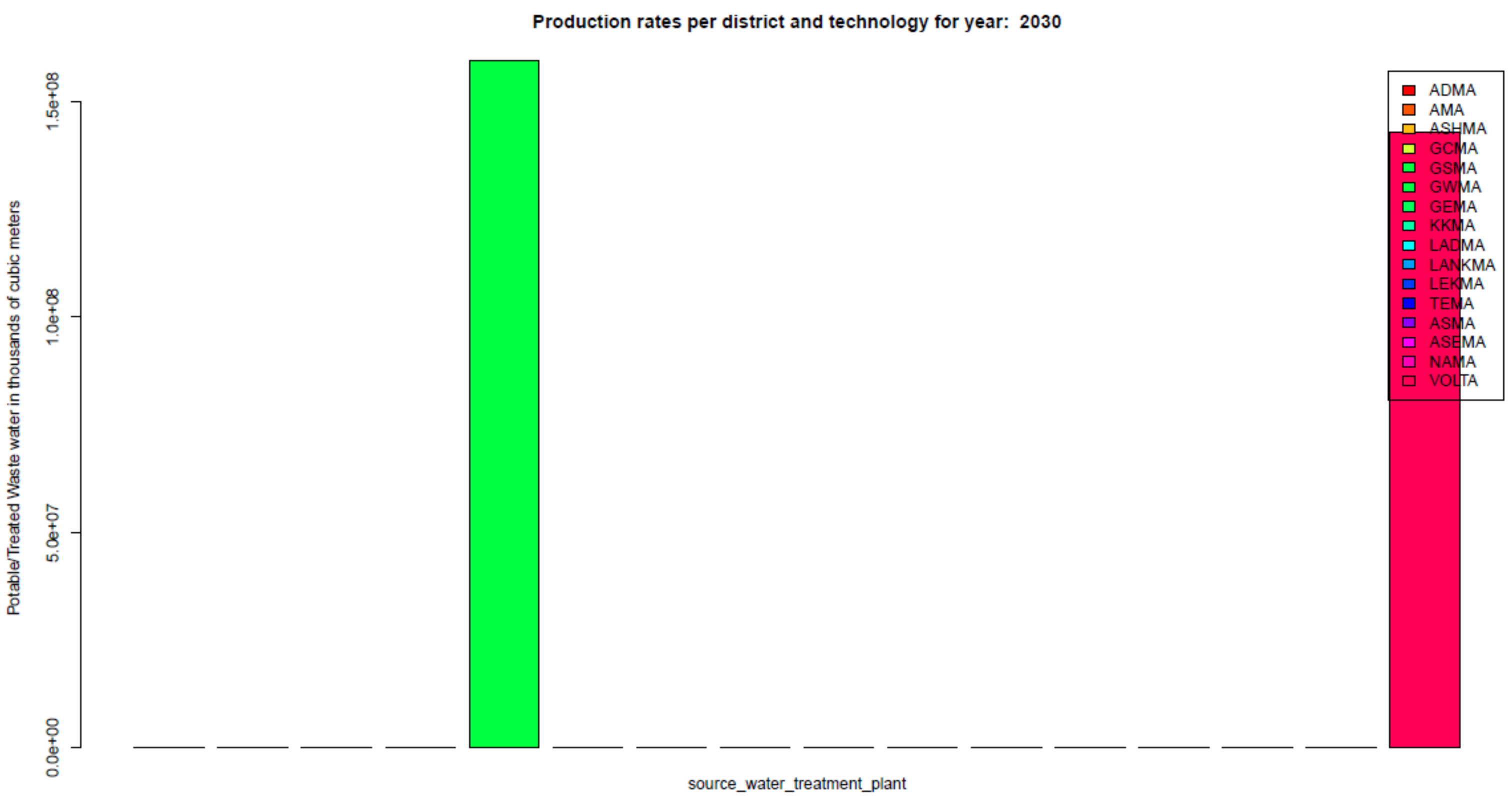



Figure 1.1 – Model generated graph production rates per year for source water-treatment plants in the **City-Wide Scenario** in 2030

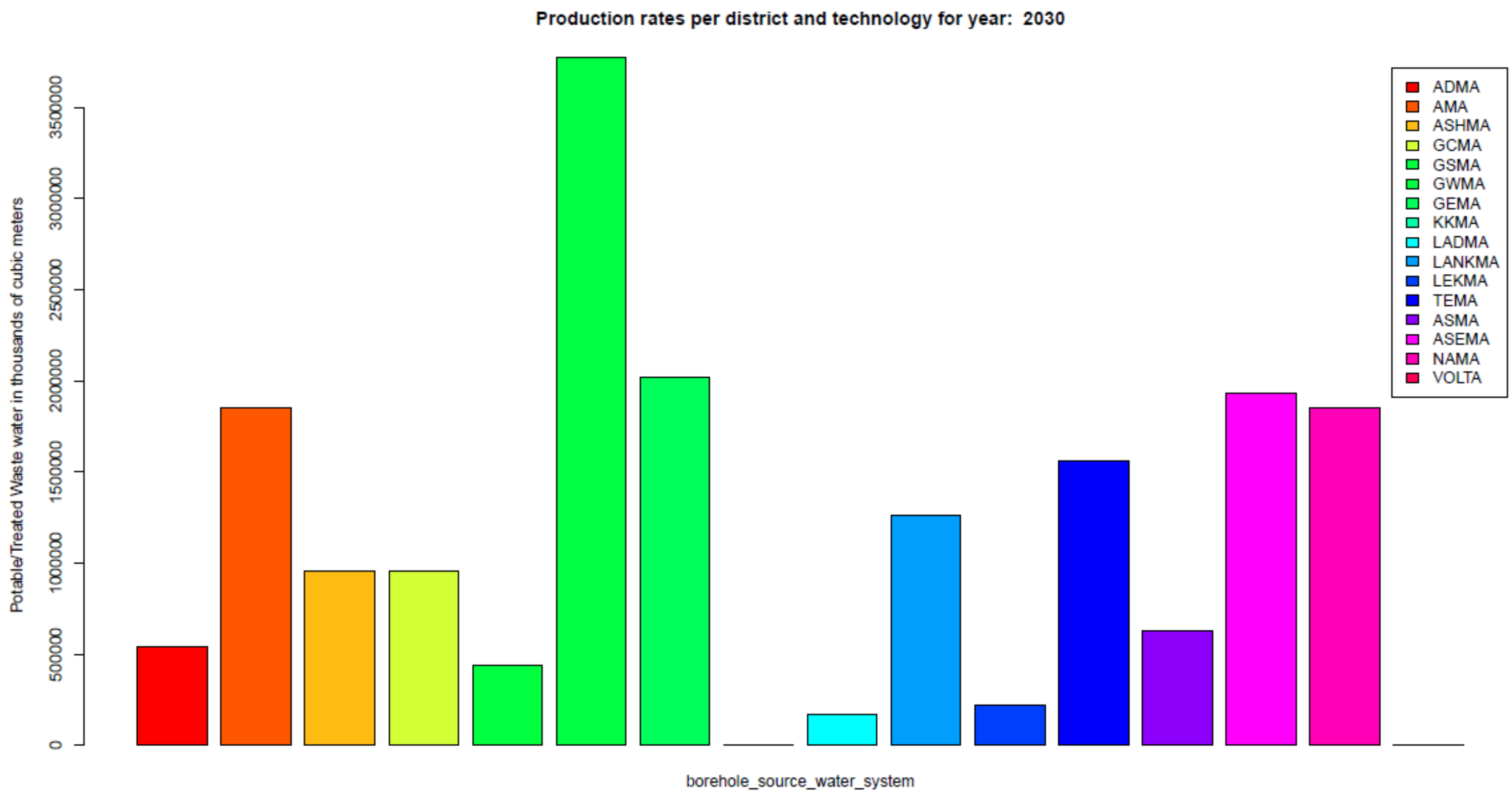
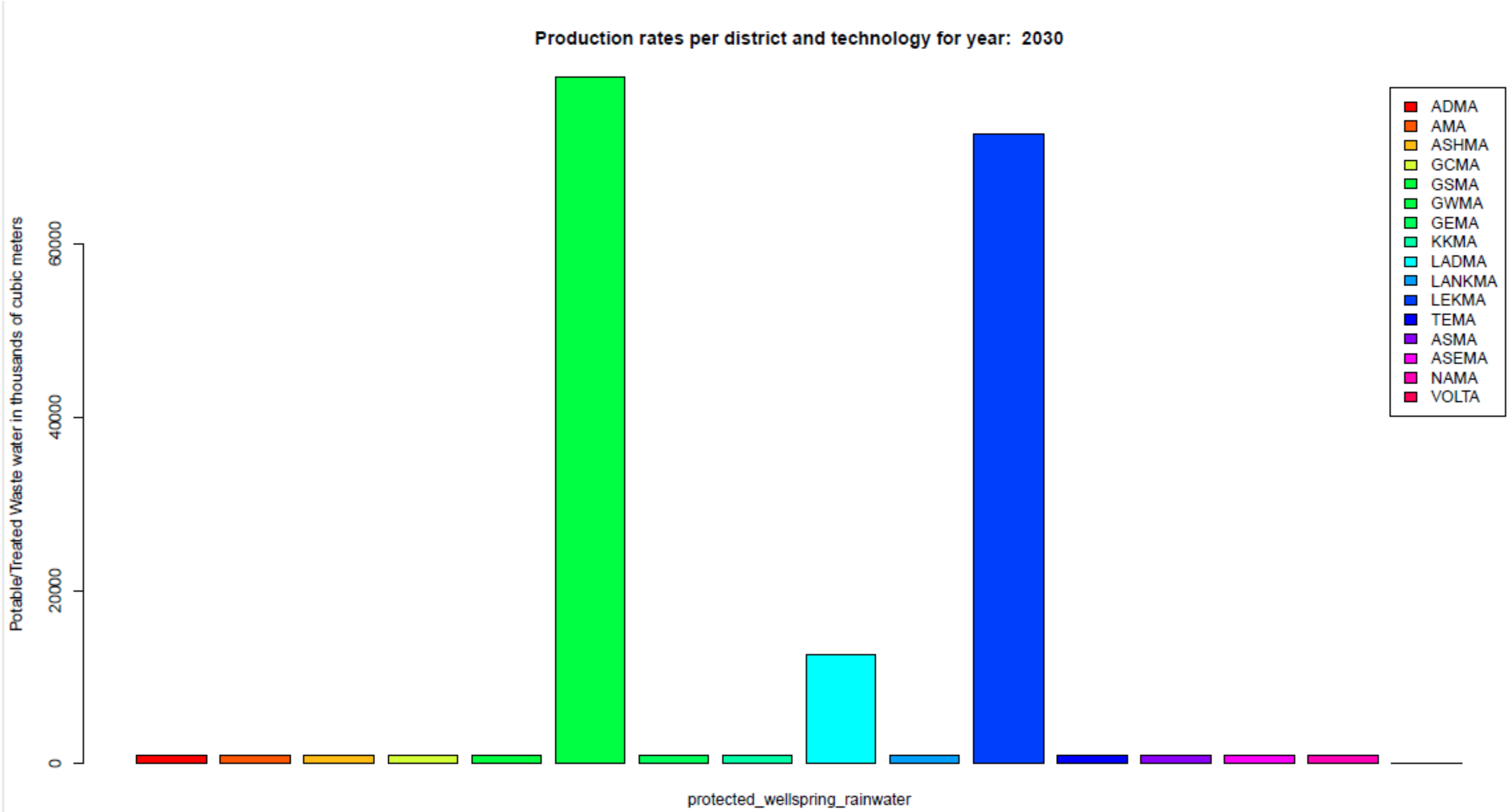



Figure 1.2 – Model generated graph for production rates per year for boreholes in the **City-Wide Scenario** in 2030.



Production rates per district and technology for year: 2030
Potable/Treated Waste water in thousands of cubic meters
0
20000
40000
60000
protected_wellspring_rainwater
ADMA
AMA
ASHMA
GCMA
GSMA
GWMA
GEMA
KKMA
LADMA
LANKMA
LEKMA
TEMA
ASMA
ASEMA
NAMA
VOLTA

Figure 1.3 – Model generated graph for production rates per year for improved wells, improved springs, and rainwater collection in the **City-Wide Scenario** in 2030.

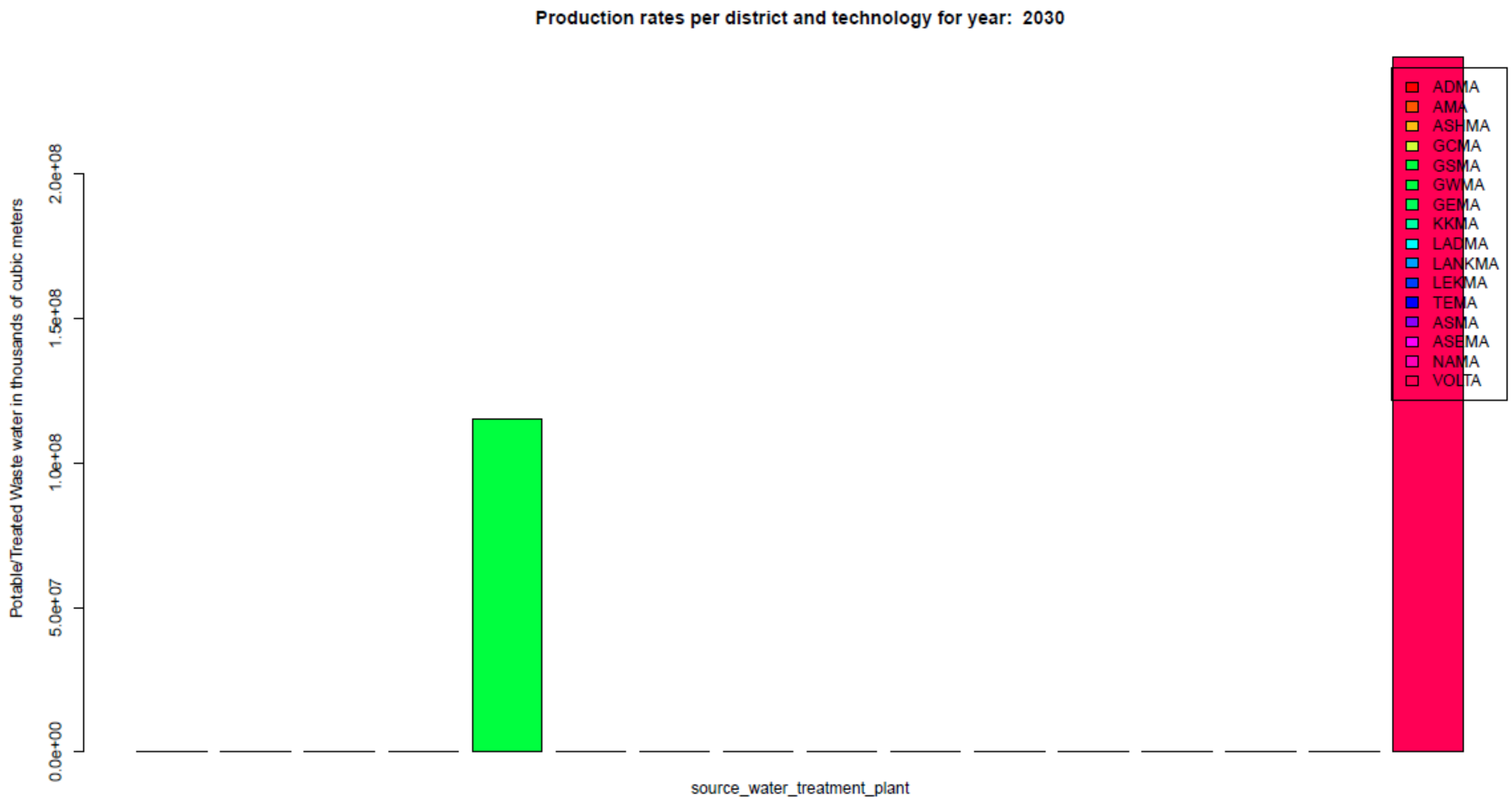



Figure 1.4 – Model generated graph production rates per year for source water-treatment plants in the **Decentralised scenario** in 2030.

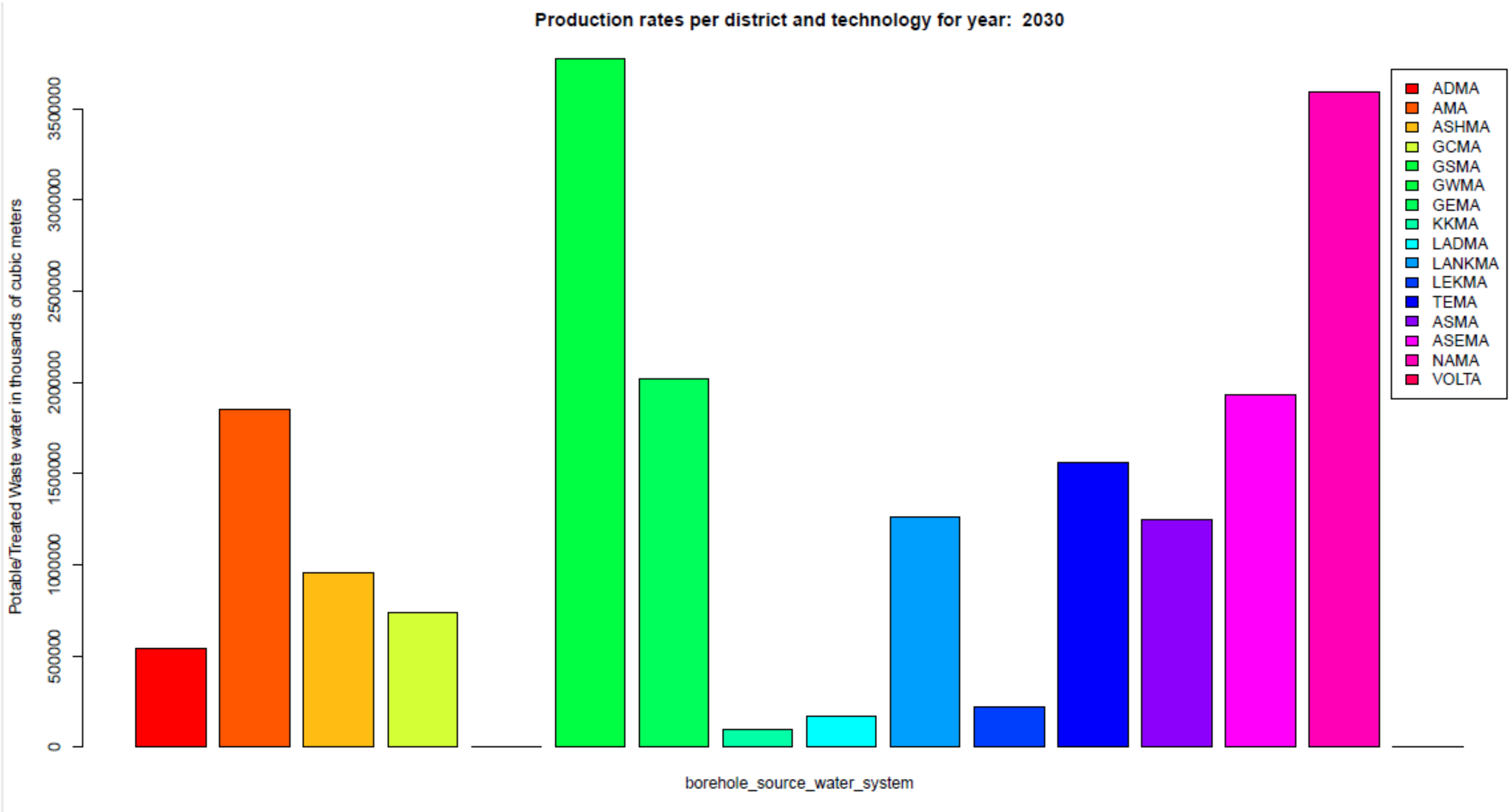



Figure 1.5 – Model generated graph for production rates per year for boreholes in the **Decentralised Scenario** in 2030.

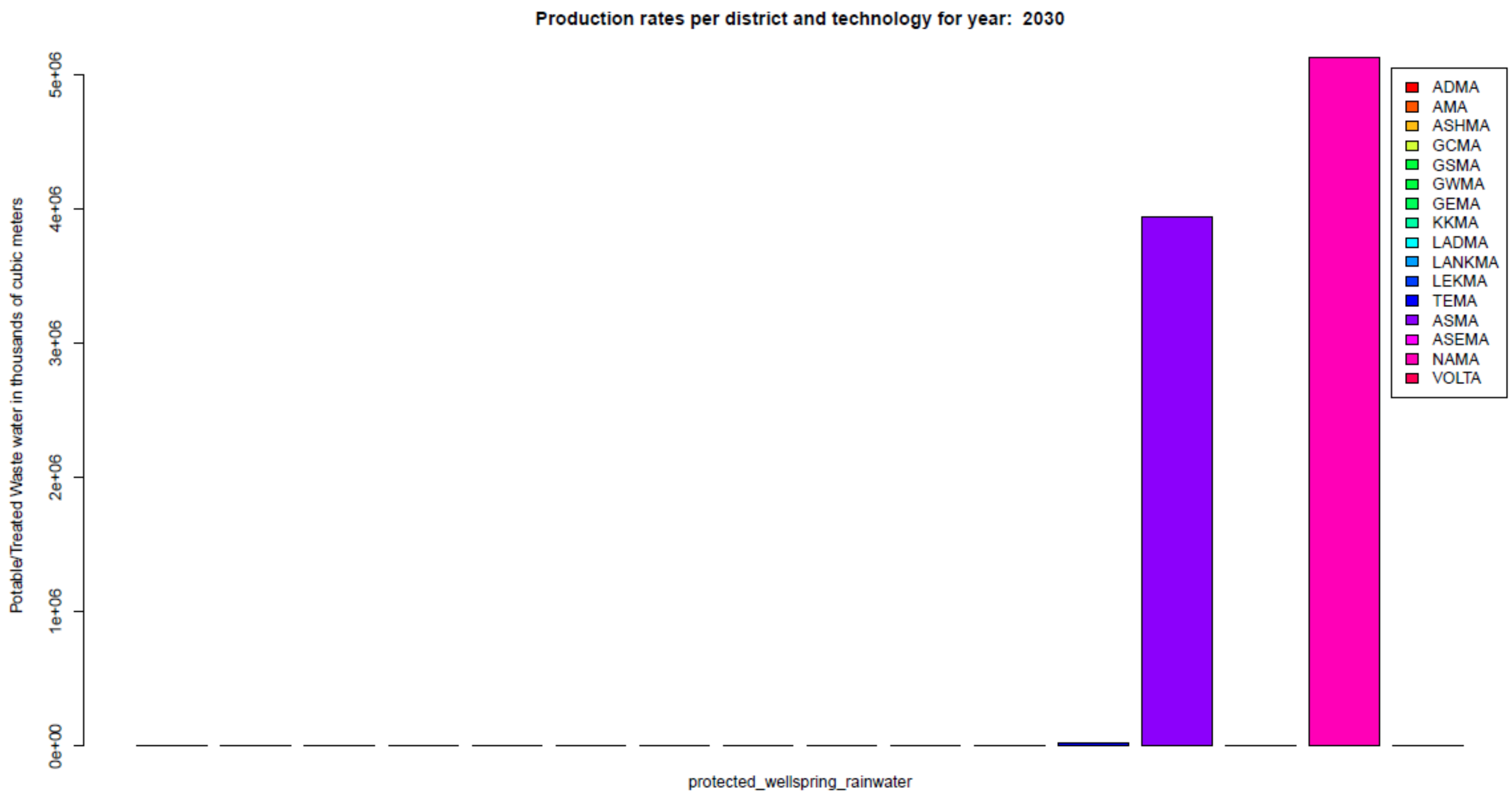

Production rates per district and technology for year: 2030
Potable/Treated Waste water in thousands of cubic meters
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
protected_wellspring_rainwater
ADMA
AMA
ASHMA
GCMA
GSMA
GWMA
GEMA
KKMA
LADMA
LANKMA
LEKMA
TEMA
ASMA
ASEMA
NAMA
VOLTA

Figure 1.6 – Model generated graph for production rates per year for improved wells, improved springs, and rainwater collection in the **Decentralised Scenario** in 2030.

### 1.4.2 Results District Values for Waste-Water Treatment

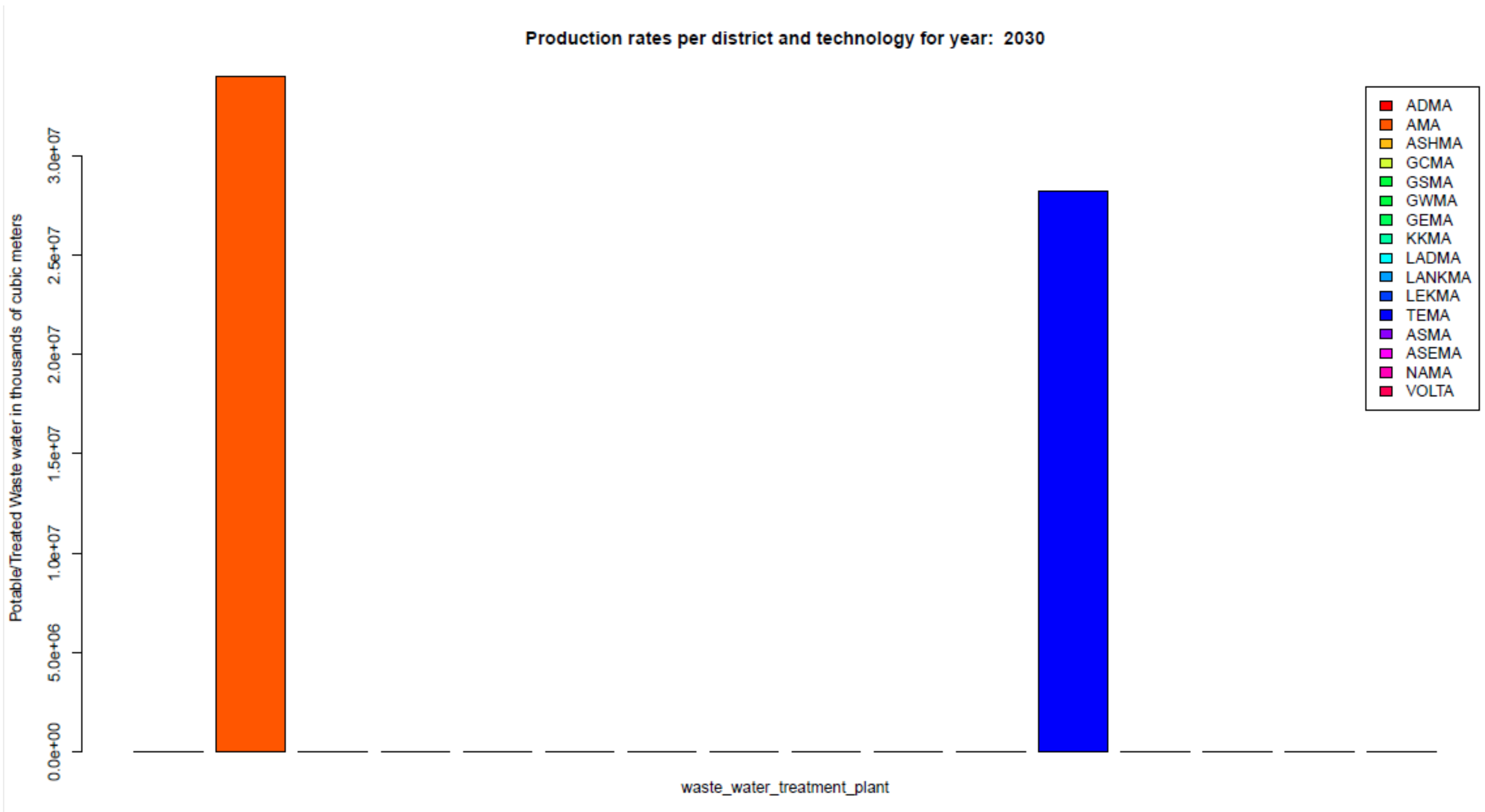


Figure 1.7 – Model generated graph for production rates per year for conventional waste water treatment plants in the **City-Wide Scenario** in 2030.

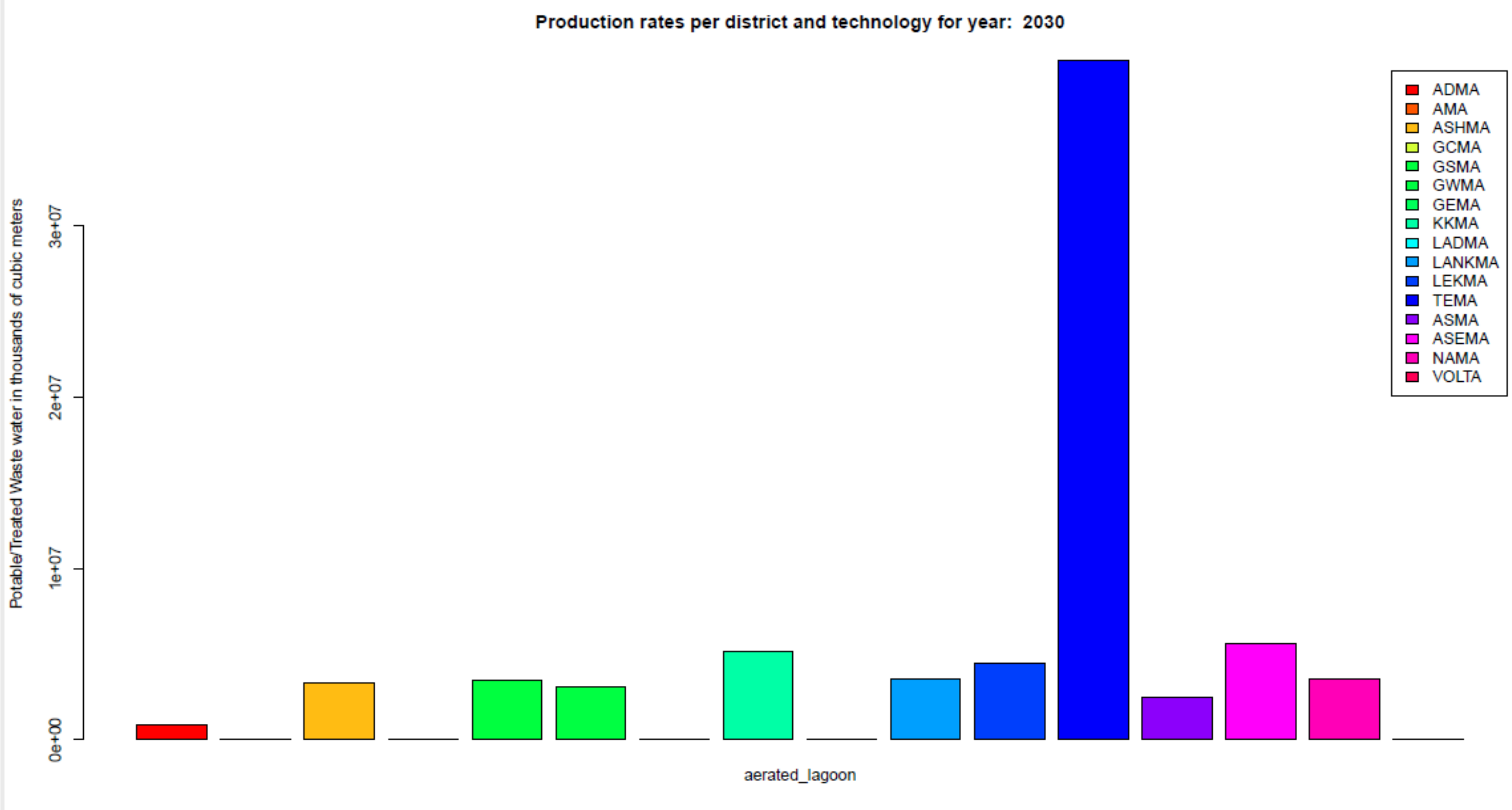
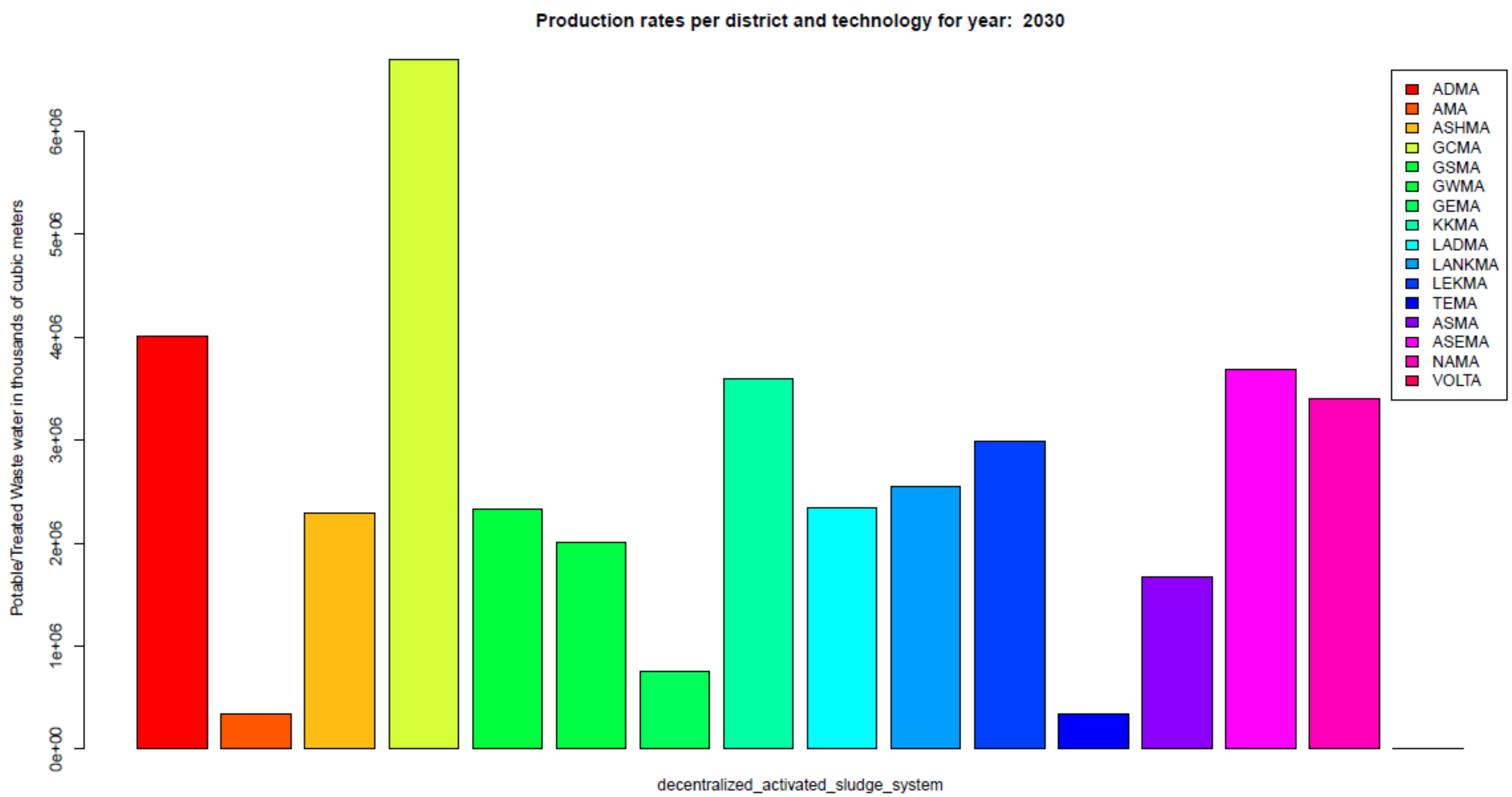



Figure 1.8 – Model generated graph for production rates per year for aerated lagoons in the **City-Wide Scenario** in 2030.



Production rates per district and technology for year: 2030
Potable/Treated Waste water in thousands of cubic meters
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
6e+06
decentralized_activated_sludge_system
ADMA
AMA
ASHMA
GCMA
GSMA
GWMA
GEMA
KKMA
LADMA
LANKMA
LEKMA
TEMA
ASMA
ASEMA
NAMA
VOLTA

Figure 1.9 – Model generated graph for production rates per year for decentralised activated sludge systems in **the City-Wide Scenario** in 2030

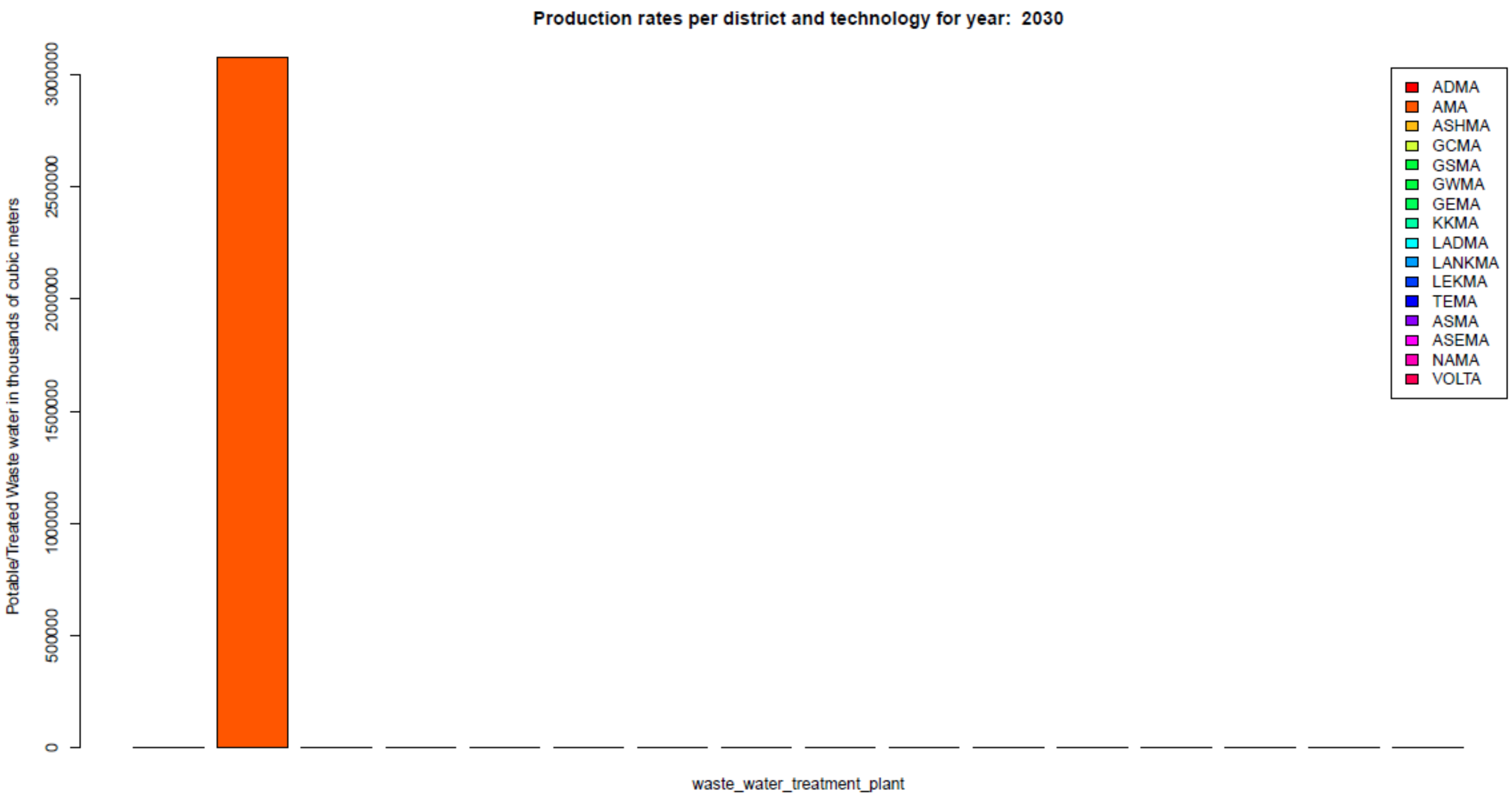



Figure 1.10 – Model generated graph for production rates per year for conventional waste water treatment plants in the **Decentralised Scenario** in 2030

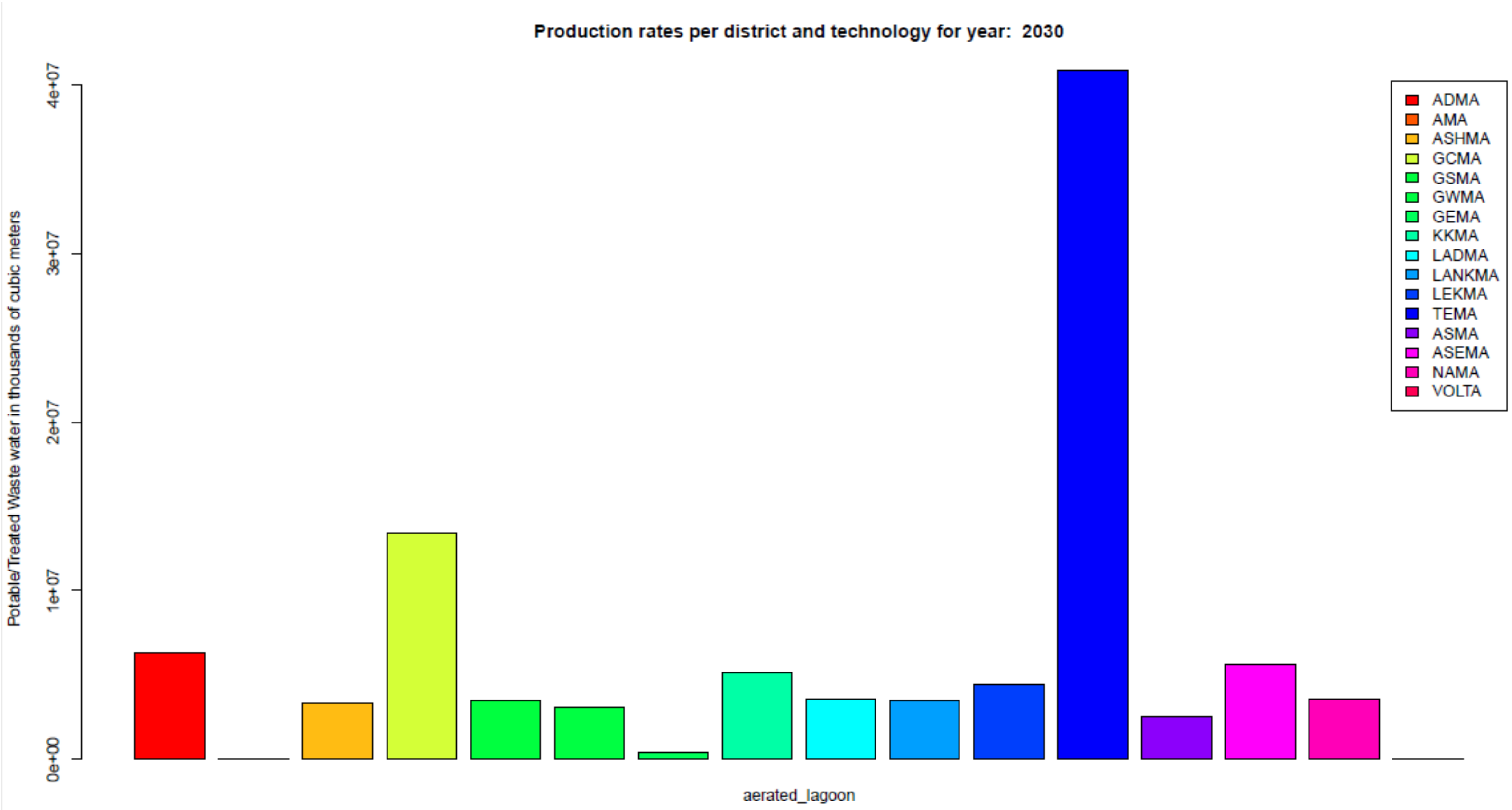



Figure 1.11 – Model generated graph for production rates per year for aerated lagoons in the **Decentralised Scenario** in 2030.

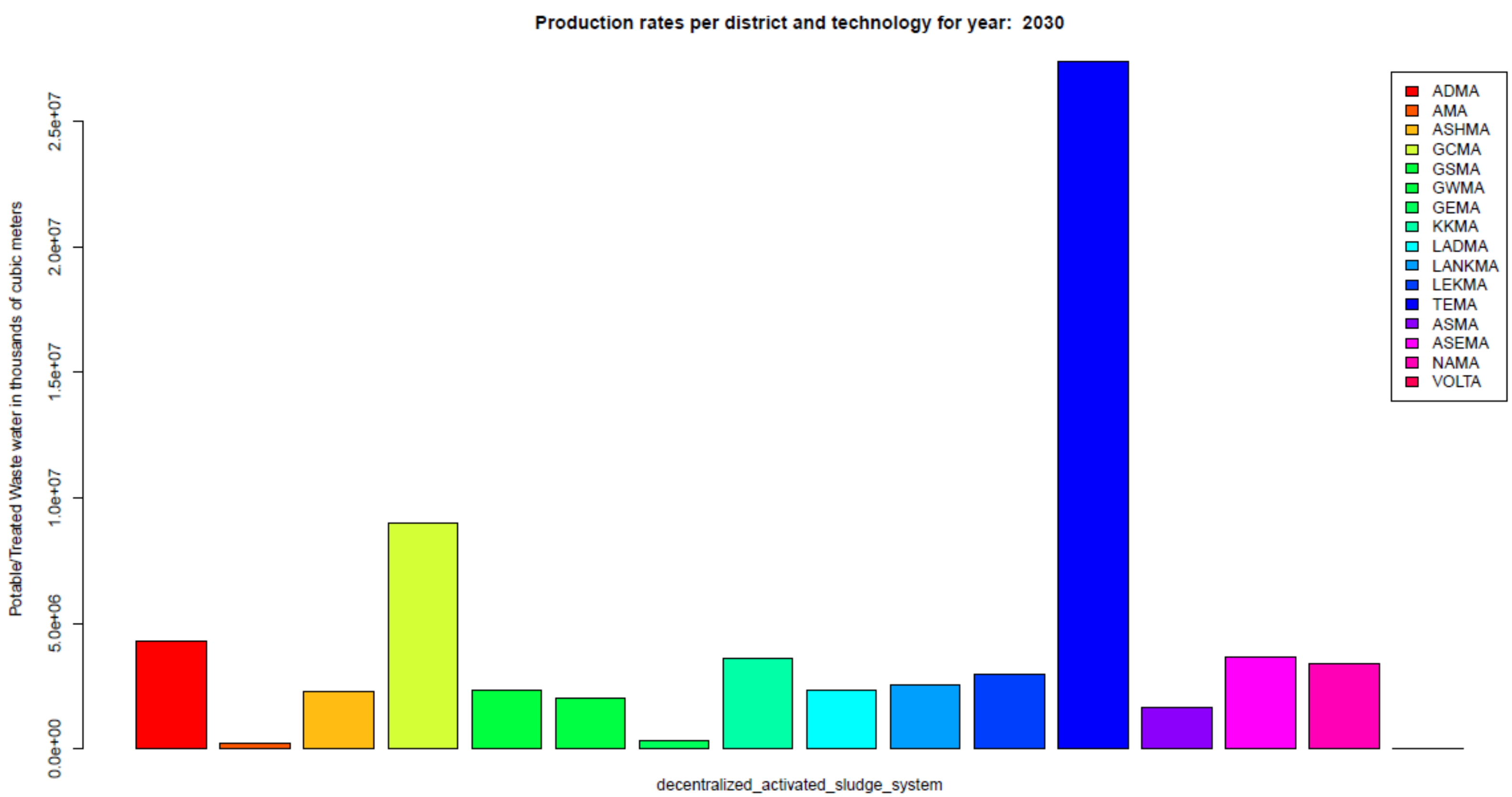

Production rates per district and technology for year: 2030
Potable/Treated Waste water in thousands of cubic meters
0.0e+00
5.0e+06
1.0e+07
1.5e+07
2.0e+07
2.5e+07
decentralized_activated_sludge_system
ADMA
AMA
ASHMA
GCMA
GSMA
GWMA
GEMA
KKMA
LADMA
LANKMA
LEKMA
TEMA
ASMA
ASEMA
NAMA
VOLTA

Figure 1.12 – Model generated graph for production rates per year for decentralised activated sludge systems in **the Decentralised Scenario** in 2030.

### 1.4.3 Results Labour and Electricity use

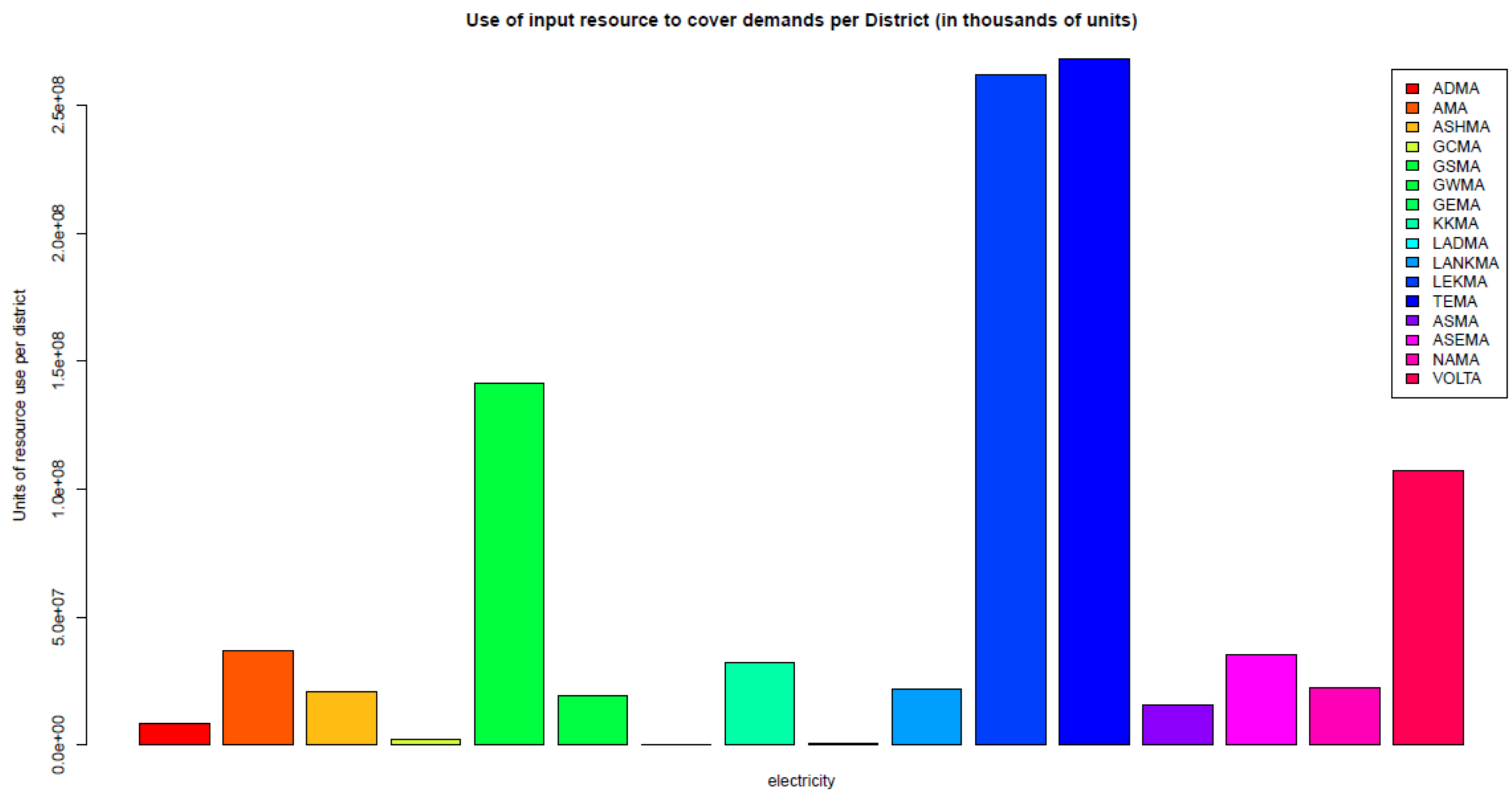



Figure 1.13 – Model generated graph of electricity use to cover water and waste-water treatment in MJ in the **City-wide Scenario** in 2030

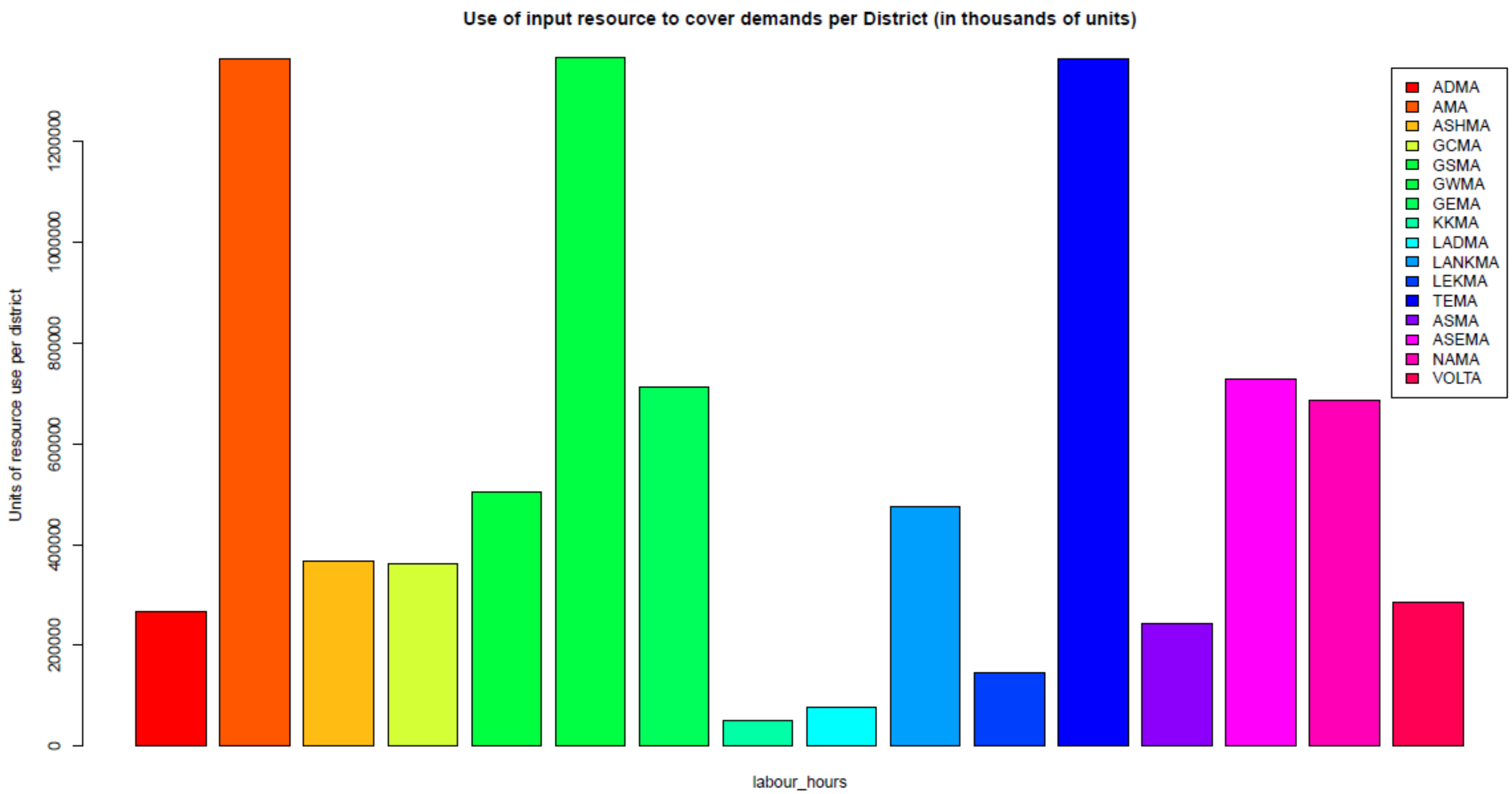



Figure 1.14 – Model generated graph of labour hour use to cover water and waste-water treatment in MJ in the **City-wide scenario** in 2030

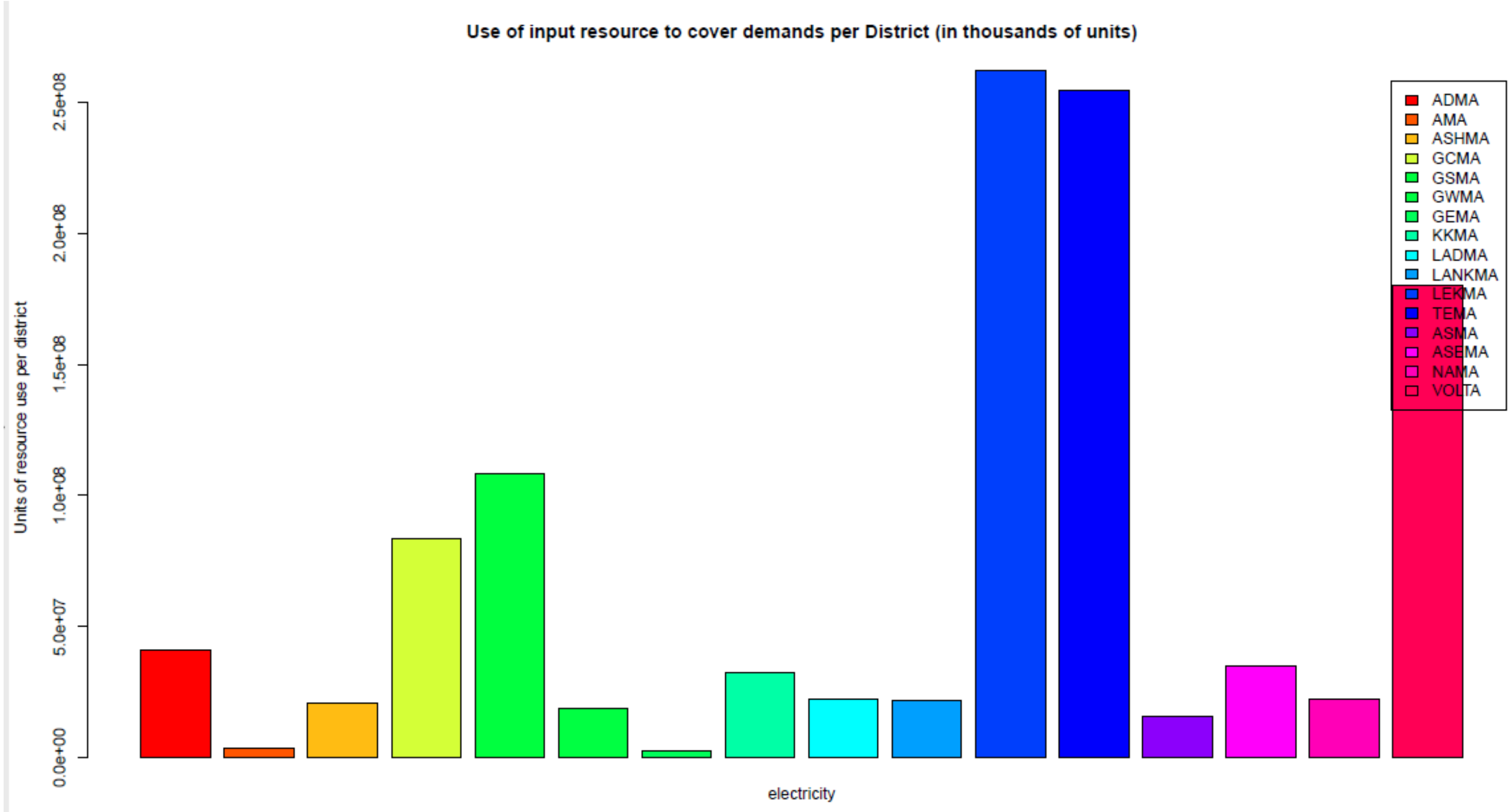



Figure 1.15 – Model generated graph of electricity use to cover water and waste-water treatment in MJ in the **Decentralised Scenario** in 2030

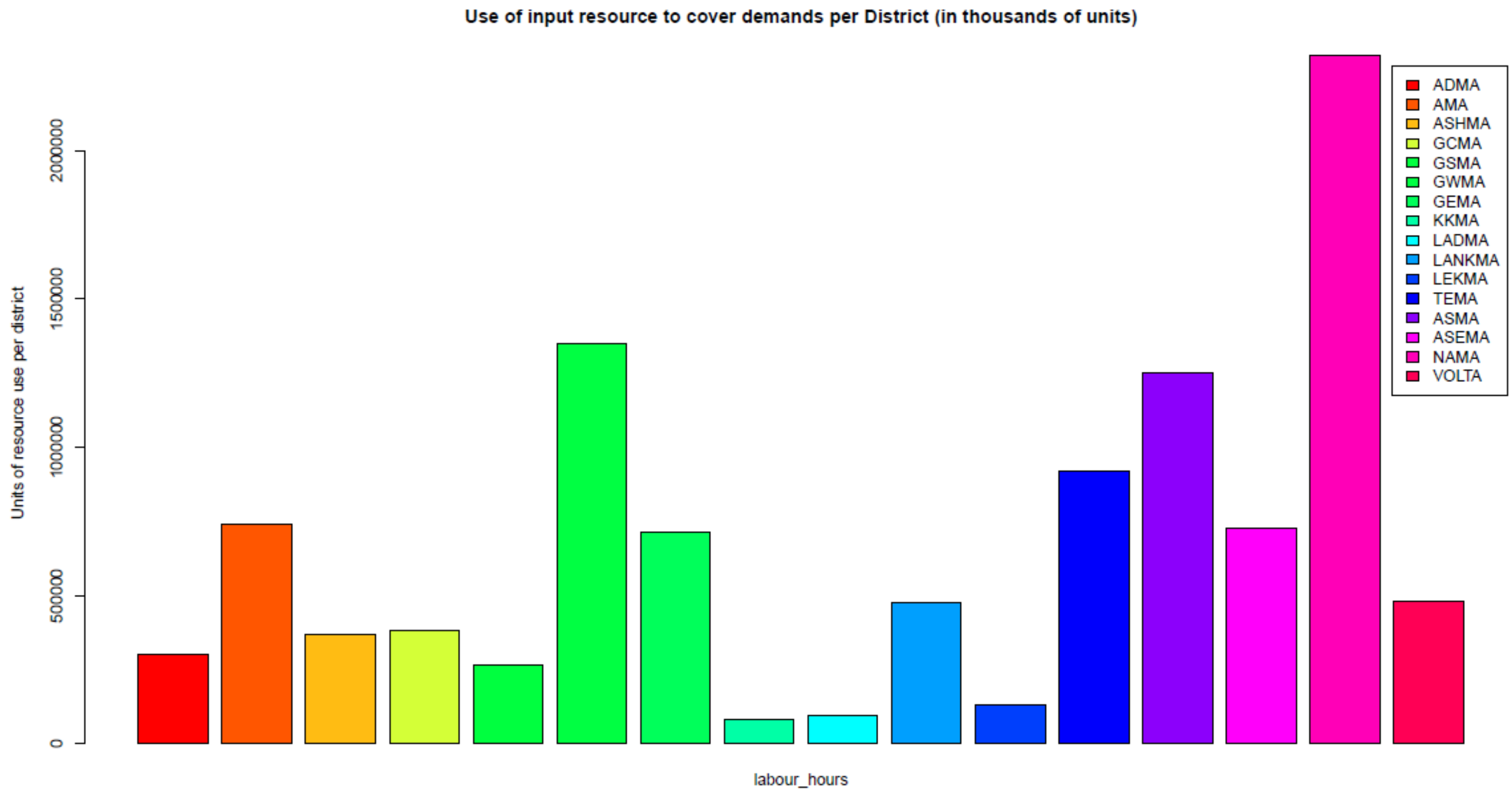



Figure 1.16 – Model generated graph of labour hour use to cover water and waste-water treatment in MJ in the **Decentralised Scenario** in 2030

### 1.4.4 Results Pipeline Flows Comparison

GAMA cells – Optimal flows (minus the leaks) of potable water (m3 per day) per district

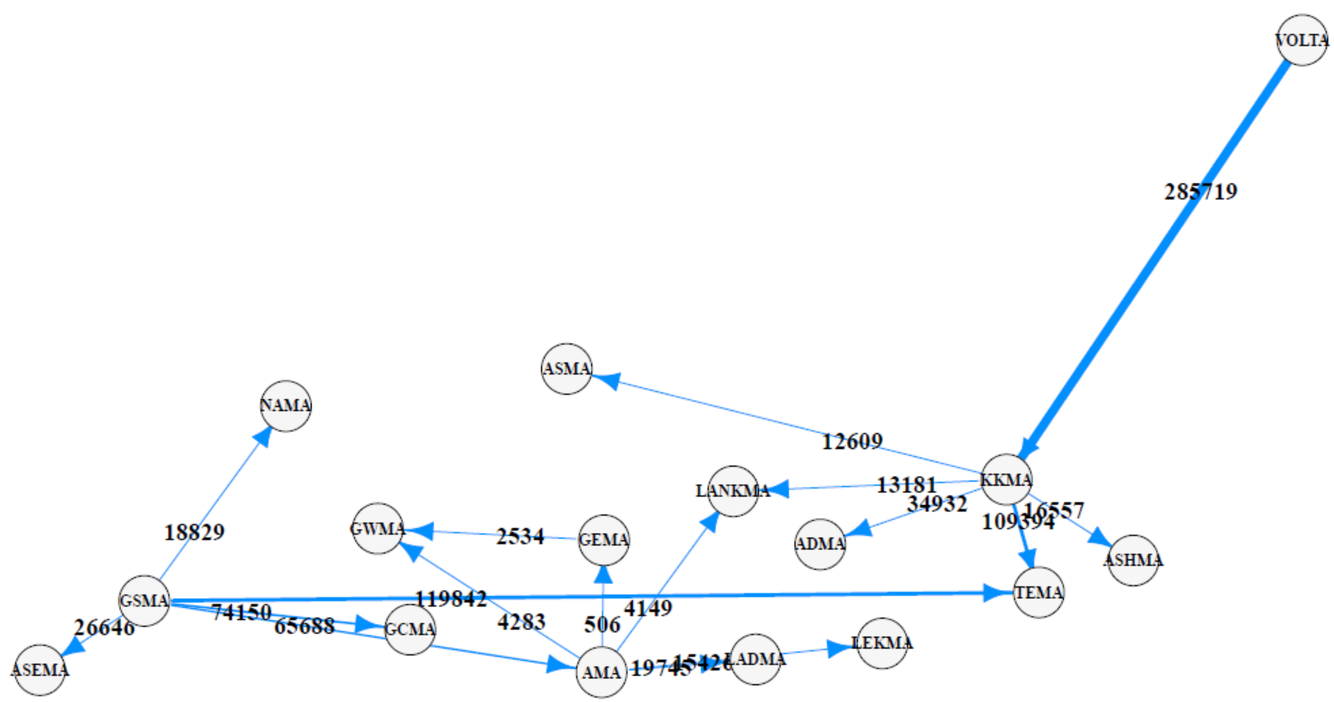


Figure 1.15 – Model generated graph of piped potable water flows per day in **the City-Wide scenario** in 2030.

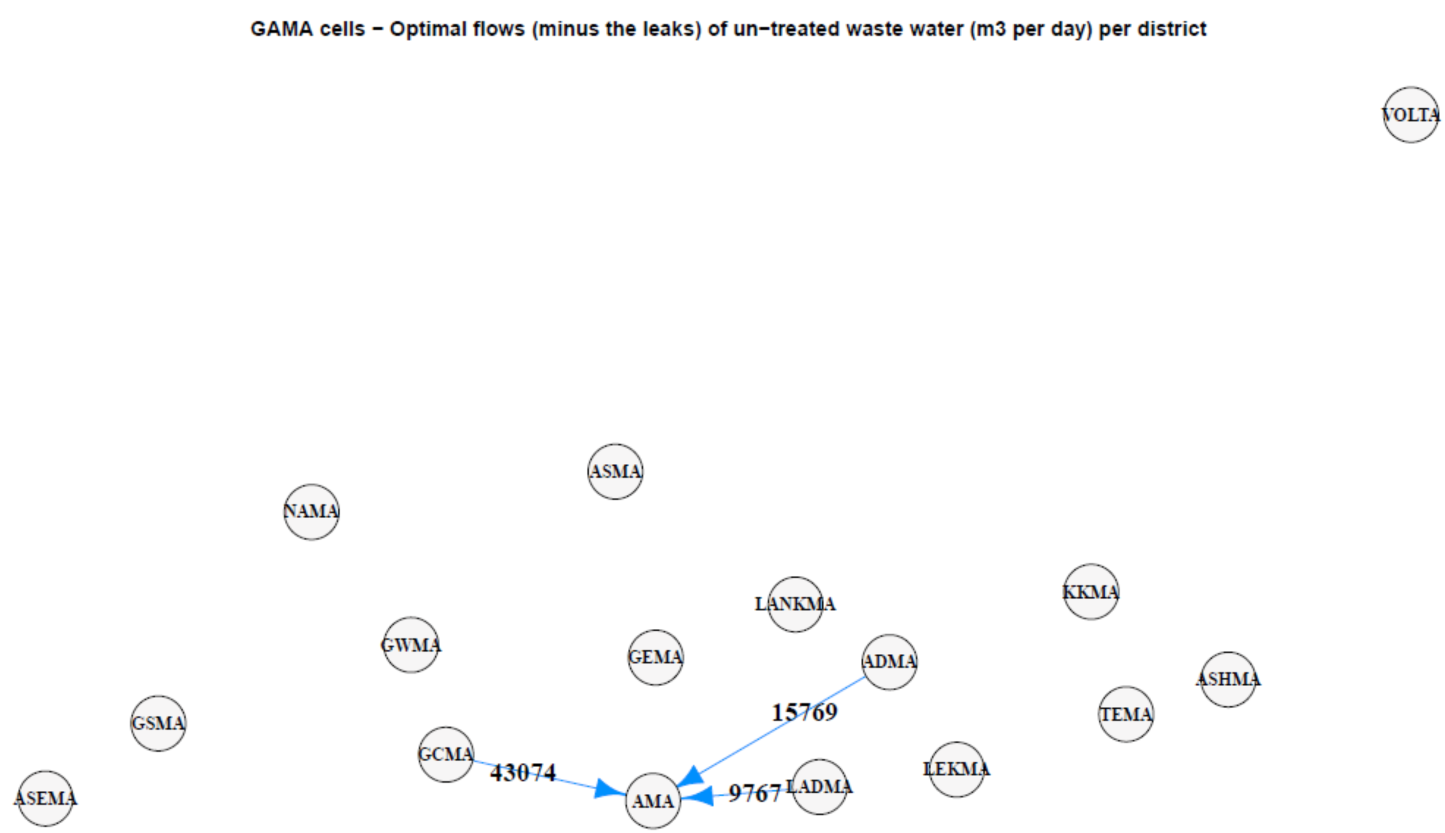



Figure 1.16 – Model generated graph of piped waste-water flows per day in **the City-Wide scenario** in 2030.

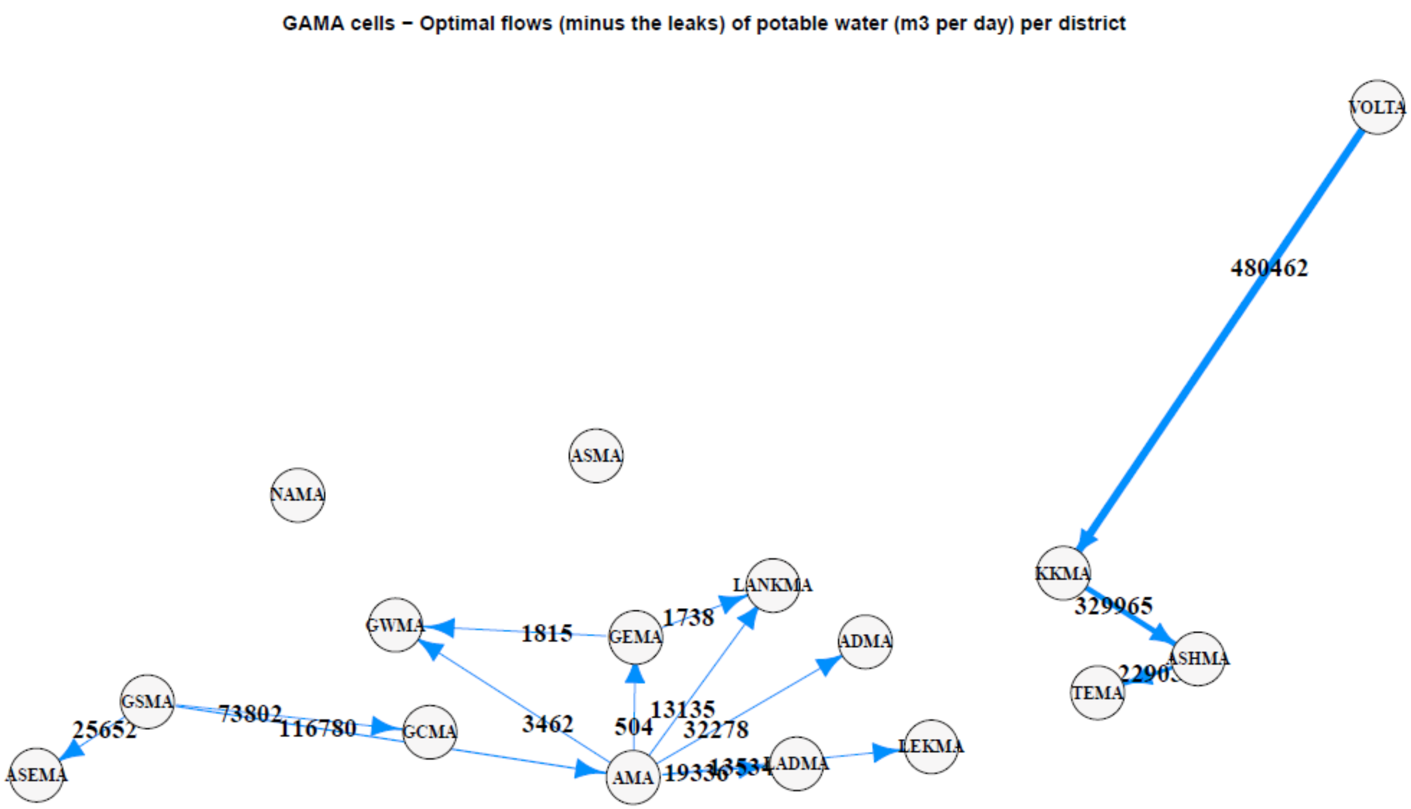

GAMA cells – Optimal flows (minus the leaks) of potable water (m3 per day) per district
VOLTA
480462
KKMA
329965
ASHMA
TEMA
NAMA
ASMA
LANKMA
1738
GWMA
1815
GEMA
ADMA
GSMA
73802
116780
GCMA
25652
ASEMA
3462
504
13135
32278
AMA
LADMA
LEKMA

Figure 1.17 – Model generated graph of piped potable water flows per day in **the Decentralised scenario** in 2030.

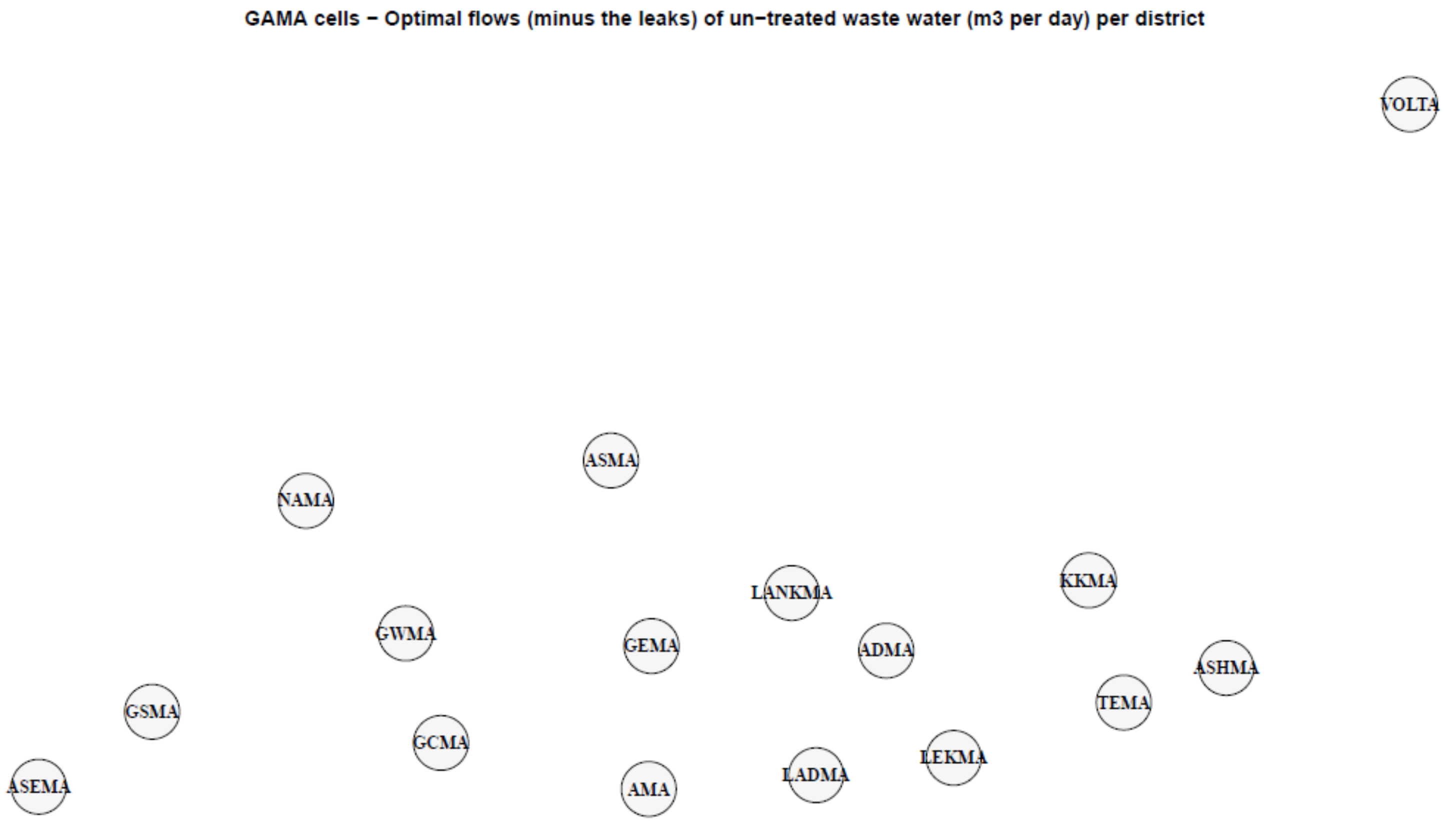



Figure 1.18 – Model generated graph of piped waste-water flows per day in **the Decentralised scenario** in 2030.

### 1.5 Discussion and Conclusions

The effects of effective potable water pipeline system utilisation can be analysed by comparing the city-wide systems versus decentralised district scenarios, since both aim to achieve 100% improved water access and waste-water treatment in 2025. The key difference in both scenarios is that no additional water or waste-water pipes can be built in the decentralised case, whereas all possibilities are open in the city-wide scenario.

In the decentralized case to supply potable water instead of building a substantial amount of local boreholes and improved springs and wells. This is because the model calculates that it is more cost effective to substantially expand potable water treatment capacity. A total potable water treatment via large centralised plants of 688,500 m3/day by 2025 is built in the simulation at Volta River and lake Weija. The additional production is then flown around in the pipe network which exists between districts, based on the maximum flows allowed in the model. This is found to be highly cost-ineffective, however, in comparison this with the city-wide case where new connections between districts can be built. To meet 100% potable water demand conventional water treatment at the Kpong site and lake Weija is only expanded by 561,000 $m^3$ per day thanks to more efficient pipe distribution, by the construction of six new large trunk lines between different districts.

The social and financial effectivity of the city-wide scenario can be found in the investment costs, job changes, and operational cost per citizen. The total investment cost as such in the city-wide system scenario is 1 billion USD by 2025 to meet 100% potable water demands, versus 1.6 billion USD in the decentralised scenario. The operational cost was found to be nearly 30 million USD higher however per year, with a total cost to operate water and waste-water treatment of 165 million USD in the decentralised versus 136 million USD in the city-wide scenario, due to more expansive infrastructure requirements. When translated to the total cost per inhabitant in the city per year, also taking into account population growth, the values are fairly favourable. In the baseline scenario the costs for 2015 were estimated at 37.2 USD per year. These costs are reduced per person to 24 USD per person per year in the city-wide scenario, and 29.1 USD per person per year in the decentralized scenario. The implementation should therefore from an operational cost perspective improve the socio-economic situation of people, as less needs to be charged for water on average. However, the challenge remains for the many households that will have difficulty to afford these values altogether, even if they are lower on average as their income is less than several hundred dollars on an annual basis.

Jobs were found to increase substantially in the decentralized district scenario, whilst they increased on a limited basis in the city-wide systems situation. This is because the decentralized borehole technology for potable water utilizes a lot of labour to maintain each borehole, when done adequately. Total job increases ranged from the 2015 level of 3081 for all water and waste-water treatment and distribution in 2015, to around 4328 in city-wide systems, and 5170 jobs in the decentralized district scenarios.

The environmental changes of the scenarios was captured by calculating the total GHG emissions of the WASH systems. Since nearly no waste-water is treated at present the GHG emissions from water and waste-water treatment rise substantially in all scenarios. On overall they increase from around 3000-4000 tonnes in 2015 to 75,000 to 92,000 by 2025 primarily due to 100% waste-water treatment. The treatment process is fairly GHG intensive due to micro-organisms turning the sludge into either carbon dioxide, or into methane, which ends up in the environment. The lower increase in GHG emissions was found for the city-wide systems scenario, at about 75,000 tonnes by 2025, versus a value of 92,200 by 2025 for the decentralized systems scenario. The calculations does not take into account what happens with the untreated waste-water that ends up in the environment, however. A portion of this will likely be aerobically or anaerobically be converted by micro-organisms, and therefore also add up GHG emissions.

The implications for district by district versus city-wide waste-water treatment was also analysed by comparing the city-wide and decentralised systems scenarios. Total waste-water treatment needs are similar in both scenarios around 407,000 to 440,000 $m^3$ per day. The solutions opted for vary substantially, however, with an additional 258,400 $m^3$ per day of conventional central waste-water treatment in the city-wide scenario versus only 16,150 $m^3$ per day in the decentralised scenario. Instead a considerable additional amount of aerated lagoon systems and decentralised activated sludge systems are built, at 119,900 and 104,533 $m^3$ per day, in the decentralised scenario over the city-wide scenario, resulting in a total of 539,325 $m^3$ and 167,802 $m^3$ per day of treatment capacity in the decentralised scenario for these two technologies, respectively. The exchange of more centralised versus more decentralised capacity is found to less cost-effective for waste-water treatment. Total investment costs are estimated to be 1 billion USD to 2025 to meet treatment needs in the city-wide system scenario versus 0.4 billion USD for the decentralised district scenario, due to the much lower cost of smaller waste-water systems including aerated lagoons and local activated sludge treatment.

The impacts of potable water pipe leakage were investigated by setting a second set of scenarios for both city-wide and sustainable development goals, where leakage was reduced from 27% to 17% of water flowing through pipes. The impact of this reduction was found to be in the order of 100,000 $m^3$ per day less potable water losses via leakage, and 5,000 $m^3$ per day of waste-water leakage in both cases. As a consequence nearly 300 million USD lower investments in treatment capacity are required to meet 100% potable water treatment needs. Additionally, operational costs are also reduced by 10 to 15 million USD per year.

The affordability of the infrastructure expansions in terms of operational cost was examined based on potential revenue generated. The calculations assumed an ideal case where all water demands at use points are paid for based on a recent revenue value of 0.54 USD per m3 of water used, and a 35% surcharge for waste-water treatment as per the recent Public Utility Regulation Comission (PURC) set tariffs. The waste-water surcharge was only applied to households with access to waste-water treatment, based on the calculated improved waste-water % access value. It was found that by 2025 in the city-wide and SDG scenario costs were about equal to revenue in this ideal situation in 2025, whereas in the decentralised situation the system has a net annual negative cost of 32 million USD. Only in the low leakage scenarios was there a surplus revenue flow of around 10 million USD due to cost reductions associated with lower production infrastructure needs.

A slower implementation of targets by five years in the year 2030 was examined in the Sustainable Development Goals scenario. Also in this scenario the model was free to choose all options for pipeline expansion and technology infrastructure. No user-set additional capacity was selected outside of on-going projects. The impacts were significant with an overall cost reduction by 2030 of 490 and 640 million USD versus the city-wide and decentralised districts scenario by 2030, respectively. The reduced investment costs are a consequence of a more effective mix of technologies. A total of 50,000 $m^3$/day and 255,000 $m^3$/day ere are lower conventional water treatment capacity expansion versus the city-wide and decentralised scenario, respectively. As well as a reduction of 161,500 m3/day in built capacity by 2030 in waste-water treatment capacity versus the city-wide scenario, versus none in the decentralised case. And comparatively a 119,900 m3/day and 77,024 m3/day added capacity of aerated lagoons and decentralised activated sludge treatment, respectively. Also the operational cost in the SDG scenario is found to be cost-effective at 153 million USD per year in 2030, versus 152 million USD in the city-wide scenario and 187 million USD in the decentralised scenario.

The main challenges with implementing these infrastructure plans relates as mentioned in the initial overview to the maintenance and financing of the projects. Especially in case of waste-water where a decentralized approach is taken there is difficulty for MMDAs to attract private sector finance, as well as national government funds. In addition a challenge as observed for waste-water treatment is the operational situation of the plants. To overcome the maintenance issues new projects for faecal sludge when donor funded are now often inclusive of at least 5 years of funded operational & maintenance support. Another potential issue is spatial area especially for the waste-water treatment using aerated lagoons. The spatial extent of lagoon based infrastructure is large with a seven pond system requiring around 225,000 $m^2$ of space, such as the broken down system at TEMA community 3 within GAMA. In particular districts that are densely populated, such as for instance AMA or La-Dade Kotopon in the use case there may not be enough space to operate such a system. The spatial constraints due to the fine granularity mapping needs are not yet taken into account in the solution calculation, however.

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# resilience.io Use Case 2: Examine the possibilities and costs of increasing household access to improved potable water sources

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| **Created:** | May 2016 |
| **Authors:** | Rembrandt Koppelaar (IIER), Xiaonan Wang (ICL), Koen van Dam (ICL), Harry Triantafyllidis (ICL), Hannes Kunz (IIER), Nilay Shah (ICL) |

## 2.1 Overview

The capital city of Ghana and its neighbouring administrative districts form the Greater Accra Metropolitan Area (GAMA). A rapidly growing metropolitan region where efforts to improve the water, sanitation, and hygiene (WASH) situation have yielded mixed results. Household access to piped water grew by 81% to 83% from 2000 to 2010 and access to public and private improved toilet facilities increased from 58% to 81% (Twum-Baah et al. 2005; Bentsi-Enchill et al. 2013). However, the percentage of total wastewater treated, including human excreta, declined from around 10% to near zero between 2000 and 2010, whilst the population of GAMA grew from 3 to 4 million people.

The second use case lies on knowledge support for GAMA communities, MMDA officers, and the Community and Water Sanitation Agency (CWSA) to design and appraise plans to provide greater access to improved drinking water sources, such as local boreholes and water taps, water pipelines, and protected springs and wells. The use case draws from the definition of improved water sources by the World Health Organization (WHO), and the standards for access as set by the MWRWH and the MLGRD, in the National Strategy for Community Participation in Management of Urbans Wash Services.[3] In this plan safe water delivery is defined on the basis of the Joint Monitoring Programme (JMP) for Water Supply and Sanitation by WHO and UNICEF, which supplied the concept of "improved water sources". [4]

[3] The definitions of standards for access relate to distance, quality, affordability, reliability, and sustainability of water supplies.

[4] In the definition by WHO and UNICEF an improved drinking-water source is one that, "*by the nature of its construction and when properly used, adequately protects the source from outside contamination, particularly faecal matter*". Apart from piped water, several other standalone sources are also regarded as improved drinking water. More details about the water sources can be found in Figure 1 on the left. It is also necessary to have hygienic, durable and enough water storage to guarantee continuous water supply. In the context of GAMA the

The focus in the use case lies on examining how the improved water access targets could be met in entirely different ways and the implications thereof. The use case compares differences in meeting improved water access primarily for central pipe system based improved water sources, versus local pipe options such as small town systems. The geographic boundary definition of GAMA as a city region used in the use case was defined by local stakeholders using the Metropolitan and Municipal District Assembly (MMDA) structures in the country (GAMA FCA Ref. Group 2015). The definition includes 15 districts, with the Accra and Tema Metropolitan districts as the most populous and with the majority of economic activity. The calculations are carried out at both the individual MMDA level, and aggregated to GAMA in the results, in line with and in support of the development of District Medium Term Development Plans (DMTDP).

The use case is described in section 2.2. The calculation functionality and scenarios provided by resilience.io to support policy inputs is described in section 2.3. The results of the use case scenario runs are visually provided in section 2.4. Finally, conclusions from the use case are summarised in section 2.5 below.

## 2.2 Use Case Description

The framework for planning of water and sanitation in Ghana at a national level is outlined in the Water Sector Strategic Development Plan (WSSDP) for 2012 to 2025 as developed by the Ministry for Water Resources, Works and Housing. As part of the framework the aim is to provide safe water for all by the year 2025, at the urban level from 59% in 2009 to 100% in 2025.

The aim of the use case is to assess what type of interventions in the water supply system will lead to improvements in water access at the level of communities and districts within GAMA. In the use case a distinction is made between two types of systems either at large facility and pipe access or local decentralised level:

- Centralized, as water treated and provided via the large urban scale pipe network owned by the GWCL in GAMA, which is connected to large treatment facilities (Kpong WT, Weija WT, Teshie desalination)

water sources used to obtain water for drinking and non-drinking purposes are diverse and include piped sources, local boreholes, wells, and springs, tanker-truck/vendor supplied sources, open surface water bodies, rainwater collection, plus sachet and bottled water.

- Decentralized, as all systems which treat water and distribute it at local scale, typically from a few, to several hundred connected households, and in a limited number of cases up to 10,000 households for a large small town water system.

The following functionalities are tested within the use case:

- The automated calculation of the lowest investment and operational costs for improved water treatment in GAMA, based on the infrastructure changes required to meet macro-level water targets. The estimates start from the baseline situation in 2010 and from there take a five year time-step, and are inclusive of on-going water treatment expansions.
- The calculation of the revenues of improved water sales based on user set tariffs for piped water sales. The calculation enables the examination of the affordability to users relative to income levels, and the sustainability of the treatment systems based on operational expenditures and capital investment requirements.
- The ability for the user to propose new water access interventions at the level of MMDAs and GAMA, in line with the existing planning cycle, in addition to model selected interventions based on criteria.
- The ability to explore how different population evolution, migration, and economic development scenarios will affect the WASH situation, via water use and wastewater generated, which feeds into the supply treatment requirements to meet WASH targets.

The outcomes are calculated on the basis of a substantial number of input values. First, the inputs which describe the baseline 2010 situation in GAMA as described in section 1.3.1 with a minor number of amendments as outlined in section 2.3.1. Second, a number of specific data inputs which describe the parameter settings of a scenario, such as restrictions to expansion of pipelines, additional technology facilities set by the user, and budget constraints or otherwise. The data inputs are described in the following section on scenarios.

## 2.3 Scenarios for second use case

A total of six scenarios are calculated within the use case to demonstrate how the improved water access challenge can be responded to in different ways and the implications thereof. Again these are all based on a baseline scenario which calculates how water infrastructure will develop from 2010 to 2030, with no additional change beyond on-going projects.

The six scenarios include:

- **Baseline scenario**, so as to assess effects of current WASH projects and policies, based on the initial set of treatment facilities and infrastructure as established in 2010 as the starting point. On top of these on-going projects are added which have been built since 2010 or are currently in the pipeline of being built. Only projects which are both funded and have been approved by the government of Ghana and local authorities are included.
- **Baseline plus scenario,** which provides the same analysis as the baseline with the addition of a substantially larger population number due to higher immigration from outside GAMA, so as to evaluate the challenges of a different demographic evolution on improved water access.
- **Local pipe source allowed,** where the targets for 100% improved water access by 2025 can be freely chosen by the model to be met by any type of technology including centralised pipe based and local borehole type sources.
- **Central pipe source only,** where the targets for 100% improved water access by 2025 are allowed to be only met by piped water sources including public and private pipes, as opposed to decentralised local boreholes and improved wells and springs.
- **Local pipe source allowed plus,** similar to non-pipe source except with the baseline plus scenario as the underlying inputs to evaluate impacts of greater migration.
- **Central pipe source plus,** similar to improved pipe source only except with the baseline plus scenario as the underlying inputs to evaluate impacts of greater migration.

The inputs for the baseline scenario and baseline plus scenario are similar to the one described in section 1.3.1 for the water component of the model. The only difference is the Baseline plus scenario change in immigration. In this case the parameter for immigration is set by a factor 1.5 in the model input. All the waste-water components are not evaluated as waste-water treatment demand is set to 0 for purposes of this use case. The details on the non-pipe and improved pipe-source scenario sets are provided in the next two subsections prior to a summary of the scenario results in section 2.4.

### 2.3.1 Local pipe source allowed scenarios

The scenario does not prescribe any particular technologies and allows selection of all options freely. However, the allowable pipe-connections are restricted to the current water treatment network, as shown in table 2.1 below. Because of this any water treatment facilities either can only provide supply within a district, or can enable water flow to other districts from within the current pipe connection infrastructure.

*Table 2.1 – Allowable district water connections from 2010 onwards from/to with a capacity of 1800 m3 per hour*

| District | District | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA | VOLTA_RIVER |
| **ADENTA** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ACCRA_METROPOLITAN** | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **ASHAIMAN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **GA_CENTRAL** | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_SOUTH** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **GA_WEST** | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **GA_EAST** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **KPONE_KATAMANSO** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **LA_DADE_KOTOPON** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **LA_NKWANTANANG_MADINA** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **LEDZOKUKU_KROWOR** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMA_METROPOLITAN | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AKWAPIM_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AWUTU_SENYA_EAST | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NSAWAM_ADOAGYIRI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VOLTA_RIVER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 2.3.2 Central pipe source only scenarios

The difference in this scenario is that particular non-pipe technologies are removed from the input data, such that they cannot be selected in the years 2020 to beyond and supply instead has to be obtained from only pipe sources.

The technologies available for water supply from 2020 include:

- Conventional water treatment plants
- Desalination plants
- Sachet water & Bottled water

This also includes the phasing-out of existing small boreholes as well as improved wells and springs, in addition to unimproved sources of supply. In terms of available pipe connections for water transport between districts, all connections are allowed as shown in table 2.2 below.

*Table 2.2 – Allowable district water connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| District | District | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA | VOLTA_RIVER |
| ADENTA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| ACCRA_METROPOLITAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| ASHAIMAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| GA_CENTRAL | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| GA_SOUTH | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| GA_WEST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| GA_EAST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| KPONE_KATAMANSO | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| LA_DADE_KOTOPON | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| LA_NKWANTANANG_MADINA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| LEDZOKUKU_KROWOR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| TEMA_METROPOLITAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| AKWAPIM_SOUTH | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| AWUTU_SENYA_EAST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| NSAWAM_ADOAGYIRI | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| VOLTA_RIVER | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 2.4 Results Overview

*Table 2.3 – Results comparison for 1st use case water access plus changes to infrastructure*

| | Year | Baseline | Baseline plus | Local pipe source | Local pipe source plus | Central pipe source | Central pipe source plus |
|---|---|---|---|---|---|---|---|
| **Improved water % access (Production – leaks / net water demand )** | 2015 | 70.3% | 68.0% | 70.4% | 68.1% | 70.4% | 68.1% |
| | 2020 | 81.2% | 65.0% | 98.3% | 98.9% | 100% | 100% |
| | 2025 | 75.2% | 68.3% | 99.6% | 99.6% | 100% | 100% |
| | 2030 | 71.9% | 64.9% | 99.6% | 99.8% | 100% | 100% |
| **Total GAMA Population (millions)** | 2015 | 4.39 | 4.70 | 4.39 | 4.70 | 4.39 | 4.70 |
| | 2020 | 4.98 | 5.73 | 4.98 | 5.73 | 4.98 | 5.73 |
| | 2025 | 5.68 | 7.02 | 5.68 | 7.02 | 5.68 | 7.02 |
| | 2030 | 6.49 | 8.65 | 6.49 | 8.65 | 6.49 | 8.65 |
| **Total GAMA Improved Potable Water Production (m3 per day)** | 2015 | 501,060 | 512,456 | 501,403 | 512,799 | 501,403 | 512,799 |
| | 2020 | 627,063 | 652,929 | 815,497 | 935,527 | 686,347 | 774,503 |
| | 2025 | 652,297 | 722,566 | 776,143 | 1,163,862 | 790,358 | 938,103 |
| | 2030 | 705,106 | 822,555 | 1,076,491 | 1,423,869 | 882,210 | 1,117,434 |
| **Total GAMA Gross Potable Water Demands including leaks (m3 per day)** | 2015 | 616,939 | 645,650 | 617,141 | 645,841 | 617,131 | 645,833 |
| | 2020 | 710,724 | 780,459 | 823,126 | 941,320 | 686,347 | 774,503 |
| | 2025 | 778,711 | 922,022 | 778,229 | 1,166,402 | 790,358 | 938,103 |
| | 2030 | 868,899 | 1,093,010 | 1,079,031 | 1,425,117 | 882,210 | 1,117,434 |
| **Total GAMA Potable Water Leakage in pipes (m3 per day)** | 2015 | 226,308 | 228,866 | 226,505 | 229,058 | 226,495 | 229,049 |
| | 2020 | 265,758 | 270,876 | 378,160 | 431,737 | 241,381 | 264,920 |
| | 2025 | 269,594 | 293,166 | 269,112 | 537,546 | 281,241 | 309,247 |
| | 2030 | 286,041 | 323,193 | 496,173 | 655,300 | 299,352 | 347,617 |
| **Total GAMA NET Water Demands without leaks (m3 per day)** | 2015 | 390,636 | 416,783 | 390,636 | 416,783 | 390,636 | 416,783 |
| | 2020 | 444,966 | 509,583 | 444,966 | 509,583 | 444,966 | 509,583 |
| | 2025 | 509,117 | 628,856 | 509,117 | 628,856 | 509,117 | 628,856 |
| | 2030 | 582,858 | 769,817 | 582,858 | 769,817 | 582,858 | 769,817 |
| **Additional district-to district water pipe connection in no.** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 5 | 5 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 1 | 2 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 1 | 1 |
| **Additional conventional water treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 510,000 | 688,500 | 433,500 | 561,000 |
| | 2020-2025 | 0 | 0 | 0 | 357,000 | 229,500 | 331,500 |
| | 2025-2030 | 0 | 0 | 408,000 | 408,000 | 153,000 | 280,500 |
| **Additional desalination plant treatment capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Additional borehole water sourcing capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 7,675 | 7,675 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Additional improved springs, wells, and rainwater collection capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 31,171 | 39,673 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 8,923 | 14,368 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 5,974 | 11,342 | 0 | 0 |

*Table 2.4 – Results comparison for 2nd use case costs and revenues – all values in current 2015 dollars and not inflation corrected*

| | Year | Baseline | Baseline plus | Local pipe source | Local pipe source plus | Central pipe source | Central pipe source plus |
|---|---|---|---|---|---|---|---|
| **% of operational cost covered by revenues from water sales and sewerage surcharge** | 2015 | -29% | -30% | -13% | -29% | -27% | -29% |
| | 2020 | -37% | -40% | -8% | -5% | 14% | 18% |
| | 2025 | -40% | -41% | 10% | -2% | 24% | 32% |
| | 2030 | -40% | -41% | -2% | 2% | 29% | 39% |
| **% of investment coverage generated by revenues from water treatment on top of operational costs spending** | 2015 | 0% | 0% | 0% | 0% | 0% | 0% |
| | 2020 | 0% | 0% | 0% | 0% | 7.1% | 7.8% |
| | 2025 | 0% | 0% | 0% | 0% | 22.4% | 22.7% |
| | 2030 | 0% | 0% | 0% | 1.6% | 40.5% | 38.8% |
| **Capital expenditure for on-going and complete infrastructure projects on the ground since 2010** | 2010-2015 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 |
| | 2015-2020 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Capital expenditure for additional infrastructure per 5 years (billion USD)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0.98 | 1.38 | 0.75 | 0.99 |
| | 2020-2025 | 0 | 0 | 0 | 0.77 | 0.43 | 0.66 |
| | 2025-2030 | 0 | 0 | 0.87 | 0.83 | 0.32 | 0.55 |
| **Of which capital expenditure for pipeline expansion for water and treatment (billion USD)** | 2010-2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 | 0.21 | 0.23 |
| | 2020-2025 | 0 | 0 | 0 | 0 | 0.03 | 0.07 |
| | 2025-2030 | 0 | 0 | 0 | 0 | 0.04 | 0.05 |
| **Operational expenditure for infrastructure per year (million USD)** | 2015 | 108 | 118 | 89 | 115 | 105 | 115 |
| | 2020 | 140 | 166 | 95 | 106 | 77 | 85 |
| | 2025 | 166 | 211 | 91 | 126 | 81 | 94 |
| | 2030 | 190 | 258 | 117 | 149 | 89 | 109 |
| **Operational expenditure per inhabitant per year (USD)** | 2015 | 24.5 | 25.1 | 20.3 | 24.6 | 23.9 | 24.6 |
| | 2020 | 28.2 | 29.0 | 19.1 | 18.4 | 15.5 | 14.9 |
| | 2025 | 29.2 | 30.0 | 16.0 | 18.0 | 14.3 | 13.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2030 | 29.4 | 29.8 | 18.1 | 17.3 | 13.7 | 12.6 |
| **Operational expenditure spent on labour per year (million USD)** | 2015 | 15.4 | 15.8 | 23.3 | 15.6 | 15.1 | 15.6 |
| | 2020 | 17.5 | 18.7 | 21.3 | 23.5 | 7.9 | 8.9 |
| | 2025 | 18.6 | 19.6 | 20.4 | 24.8 | 1.8 | 2.1 |
| | 2030 | 19.1 | 19.6 | 23.3 | 26.2 | 2.0 | 2.4 |
| **Operational expenditure for electricity per year (million USD)** | 2015 | 2.6 | 2.6 | 10.1 | 2.6 | 2.5 | 2.6 |
| | 2020 | 12.5 | 12.6 | 8.8 | 9.3 | 8.8 | 9.2 |
| | 2025 | 12.6 | 12.9 | 8.5 | 10.6 | 9.1 | 9.9 |
| | 2030 | 12.9 | 13.5 | 10.1 | 12.0 | 9.6 | 10.9 |
| **Revenues from water sales via pipe-network[5]** | 2015 | 77.0 | 82.1 | 77.0 | 82.1 | 77.0 | 82.1 |
| | 2020 | 87.7 | 100.4 | 87.7 | 100.4 | 87.7 | 100.4 |
| | 2025 | 100.4 | 123.9 | 100.3 | 123.9 | 100.3 | 123.9 |
| | 2030 | 114.9 | 151.7 | 114.9 | 151.7 | 114.9 | 151.7 |

*Table 2.5 – Results comparison for 2nd use case environment, energy and labour*

| | Year | Baseline | Baseline plus | Local pipe source | Local pipe source plus | Central pipe source | Central pipe source plus |
|---|---|---|---|---|---|---|---|
| **Total GHG emissions in tonnes for water treatment plus distribution** | 2015 | 3860 | 3925 | 3395 | 3460 | 3395 | 3460 |
| | 2020 | 4578 | 4725 | 5191 | 5894 | 7888 | 8406 |
| | 2025 | 4722 | 5145 | 4941 | 7264 | 5432 | 6349 |
| | 2030 | 5043 | 5767 | 6761 | 8839 | 6003 | 7462 |
| **GHG emissions in kg per m3 for water treatment plus distribution** | 2015 | 7.56 | 7.52 | 6.71 | 6.69 | 6.71 | 6.69 |
| | 2020 | 7.01 | 6.96 | 6.27 | 6.21 | 11.11 | 10.56 |
| | 2025 | 6.96 | 6.87 | 6.26 | 6.17 | 6.65 | 6.58 |
| | 2030 | 6.90 | 6.80 | 6.21 | 6.15 | 6.61 | 6.52 |
| **Total sachet plastic in tonnes per day generated for water use** | 2015 | 116 | 122 | 116 | 122 | 116 | 122 |
| | 2020 | 140 | 153 | 140 | 153 | 140 | 153 |
| | 2025 | 153 | 180 | 153 | 180 | 153 | 180 |
| | 2030 | 170 | 212 | 170 | 212 | 170 | 212 |
| **Total electricity use in kWh for water treatment plus distribution** | 2015 | 35,672 | 36,427 | 35,141 | 35,896 | 35,141 | 35,896 |
| | 2020 | 173,288 | 174,980 | 121,340 | 129,858 | 121,767 | 128,043 |
| | 2025 | 174,953 | 180,060 | 118,443 | 146,709 | 126,500 | 137,129 |
| | 2030 | 178,846 | 187,695 | 140,586 | 166,031 | 132,879 | 150,766 |
| | 2015 | 69.9 | 69.8 | 69.5 | 69.4 | 69.5 | 69.4 |

5 The values assume that all water that is delivered to the end-customer will generate revenue, and that all non-revenue water that does not stem from leaks in the system is accounted for by payments.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Electricity use in kWh per m3 of water treated and distributed** | 2020 | 265.3 | 257.7 | 146.5 | 136.9 | 171.5 | 160.9 |
| | 2025 | 257.9 | 240.52 | 150.1 | 124.7 | 154.9 | 142.2 |
| | 2030 | 244.6 | 221.2 | 129.0 | 115.5 | 146.3 | 131.82 |
| | | | | | | | |
| **Total jobs in number for water treatment and distribution** | 2015 | 3133 | 3228 | 3081 | 3176 | 3081 | 3176 |
| | 2020 | 3580 | 3815 | 4346 | 4800 | 1609 | 1819 |
| | 2025 | 3797 | 4005 | 4173 | 5073 | 370 | 423 |
| | 2030 | 3905 | 4008 | 4758 | 5350 | 403 | 487 |
| | | | | | | | |
| **Labour hours in number for water treatment and distribution** | 2015 | 6,391,458 | 6,585,858 | 6,284,878 | 6,479,273 | 6,284,874 | 6,479,273 |
| | 2020 | 7,302,898 | 7,782,228 | 8,865,666 | 9,791,598 | 3,281,444 | 3,709,981 |
| | 2025 | 7,746,633 | 8,169,514 | 8,513,882 | 10,348,518 | 754,200 | 862,003 |
| | 2030 | 7,966,761 | 8,177,263 | 9,706,658 | 10,913,843 | 821,201 | 992,916 |
| | | | | | | | |
| **Labour hours in no per m3 of water treated and distributed** | 2015 | 12.5 | 12.6 | 12.4 | 12.5 | 12.4 | 12.5 |
| | 2020 | 11.2 | 11.5 | 10.7 | 10.3 | 4.6 | 4.7 |
| | 2025 | 11.4 | 10.9 | 10.8 | 8.8 | 0.9 | 0.9 |
| | 2030 | 10.9 | 9.63 | 8.9 | 7.6 | 0.9 | 0.9 |

### 2.4.1 Results District values for Water Treatment Capacity

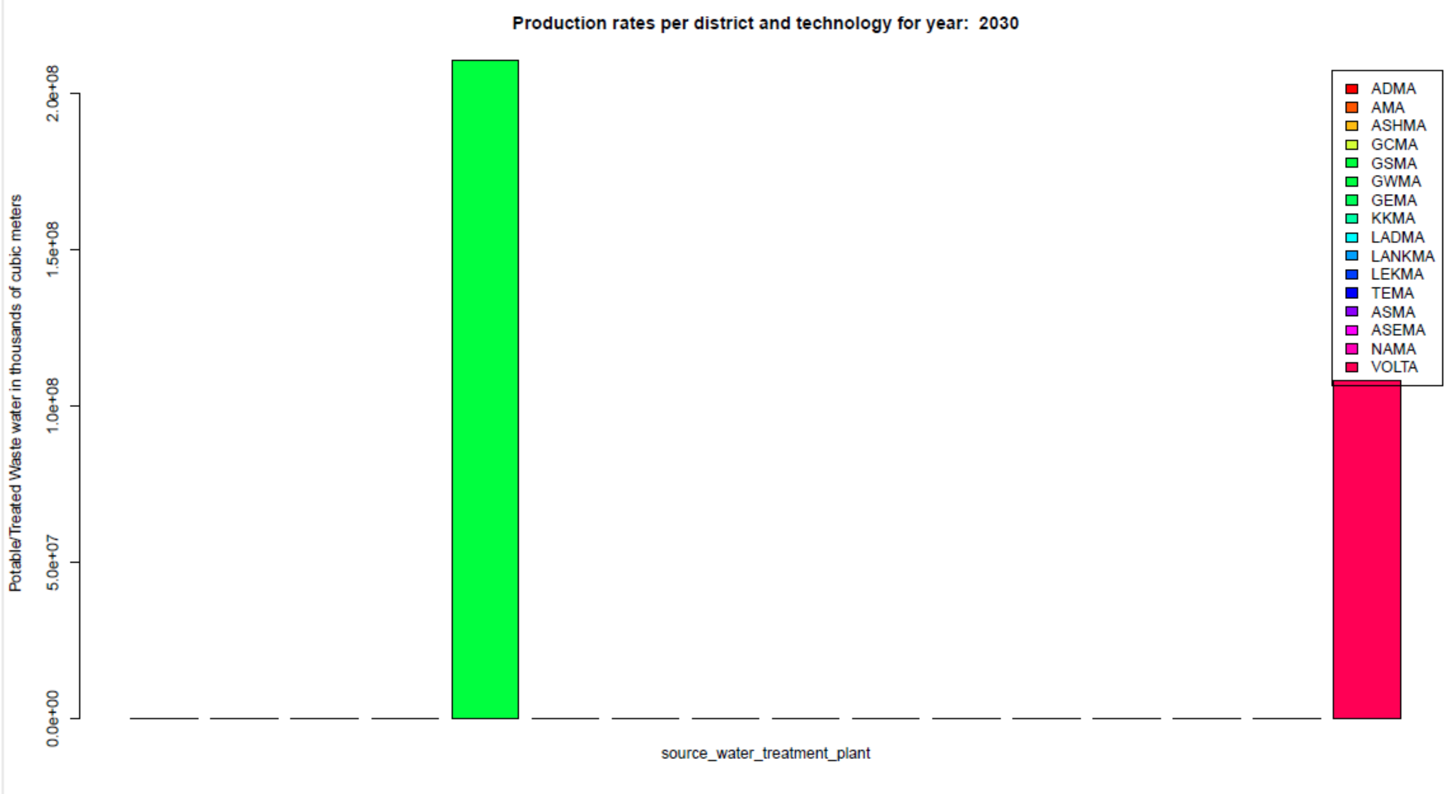


Figure 2.1 – Model generated graph production rates per year for source water-treatment plants in the **Central Pipe Scenario** in 2030

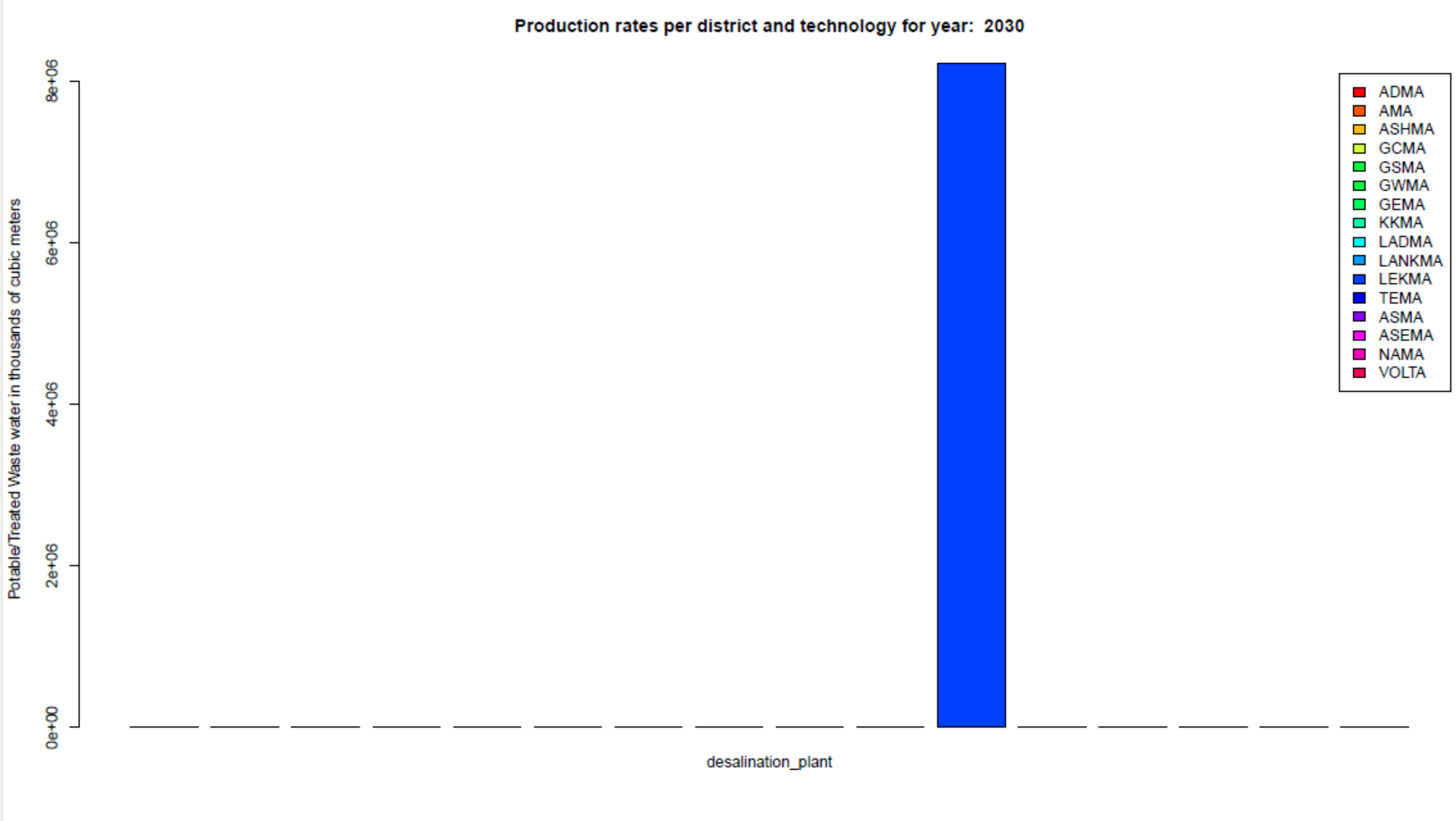


Figure 2.2 – Model generated graph production rates per year for desalination plants in the **Central Pipe Scenario** in 2030

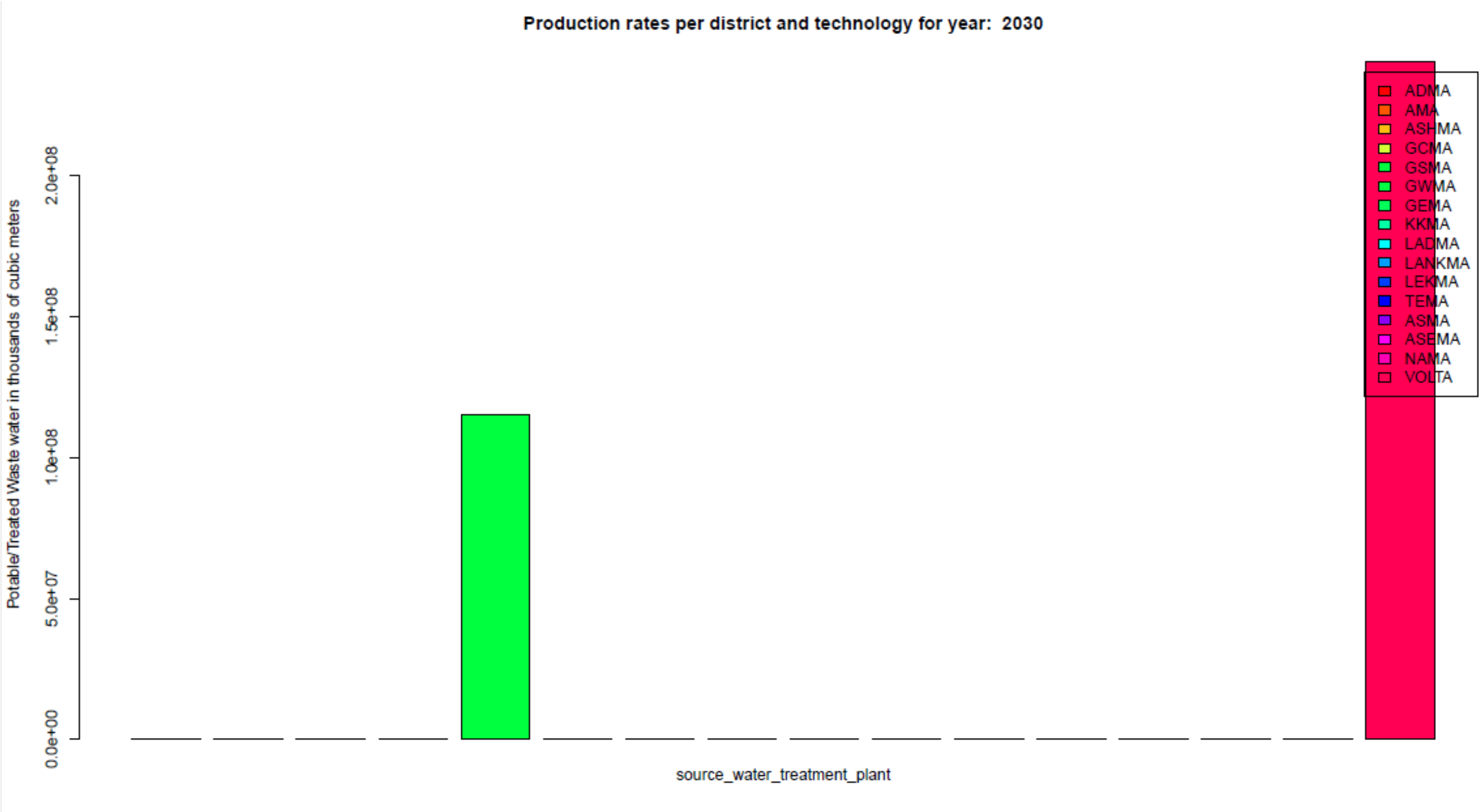


Figure 2.3 – Model generated graph production rates per year for source water-treatment plants in the **Local Pipe Scenario** in 2030

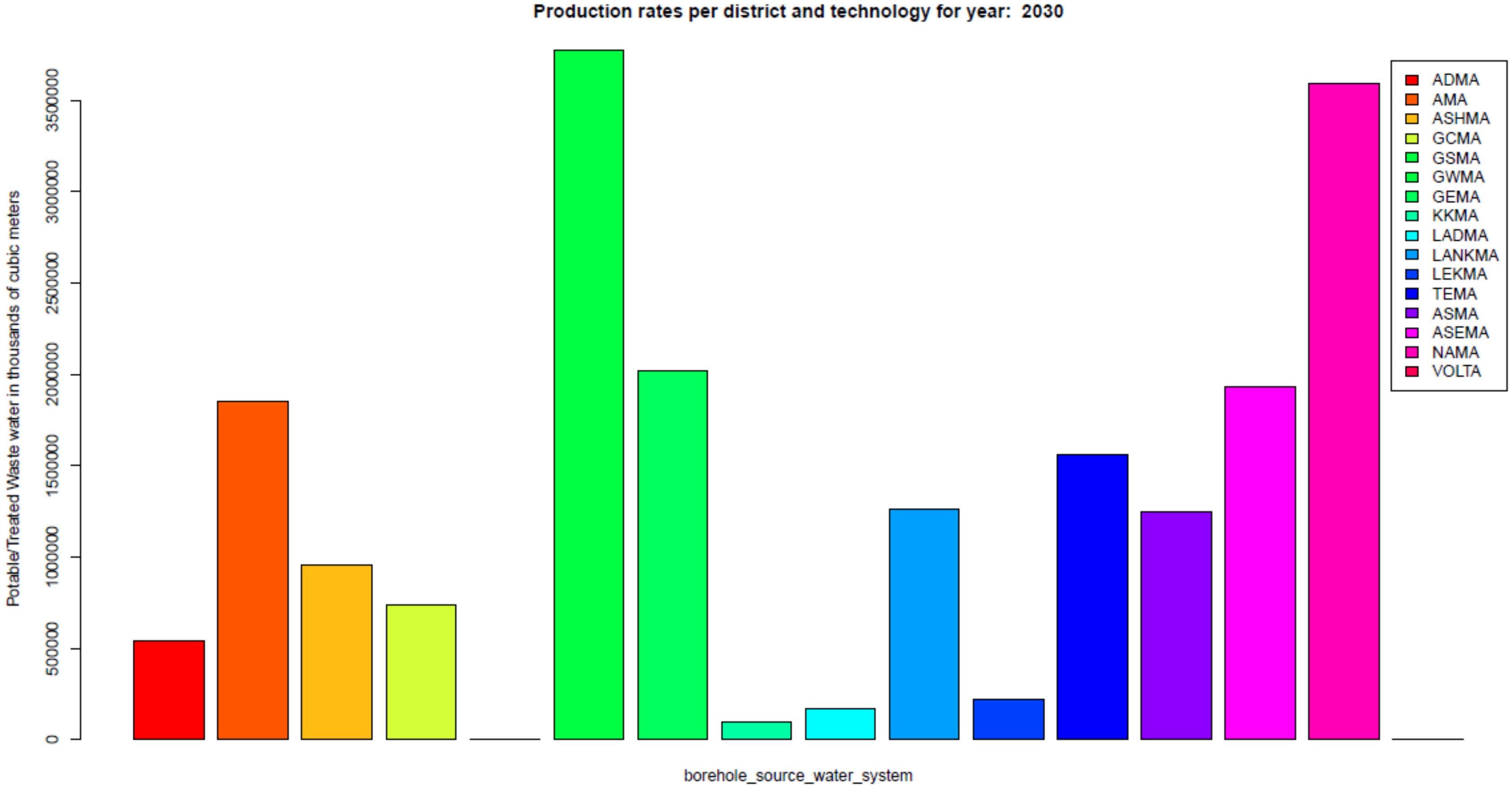


Figure 2.4 – Model generated graph production rates per year for borehole systems in the **Local Pipe Scenario** in 2030

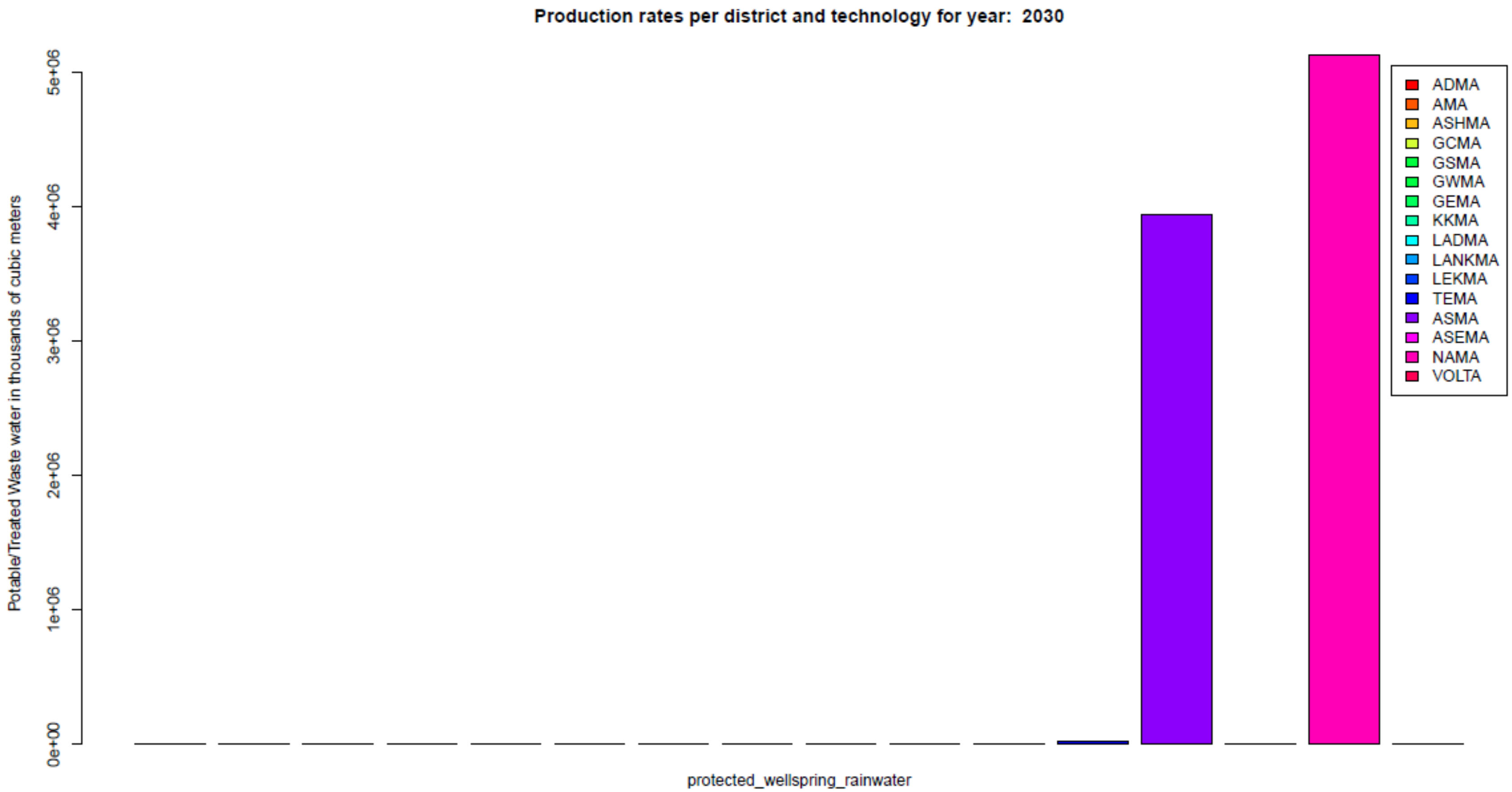


Figure 2.5 – Model generated graph production rates per year for protected wells, protected springs, and rainwater collection systems in the **Local Pipe Scenario** in 2030

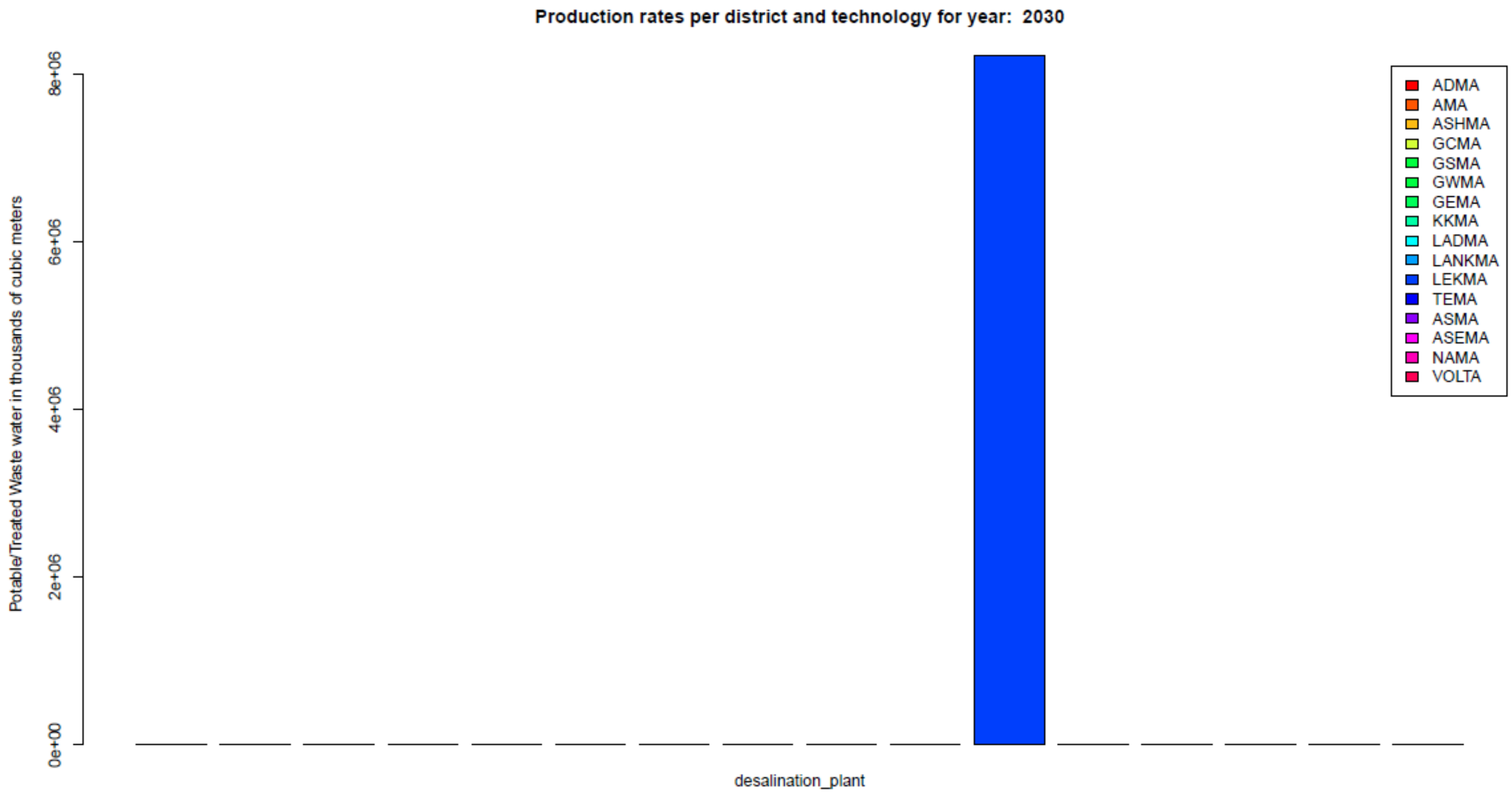


Figure 2.6 – Model generated graph production rates per year for desalination plant systems in the **Local Pipe Scenario** in 2030.

### 2.4.2 Results Labour and Electricity use

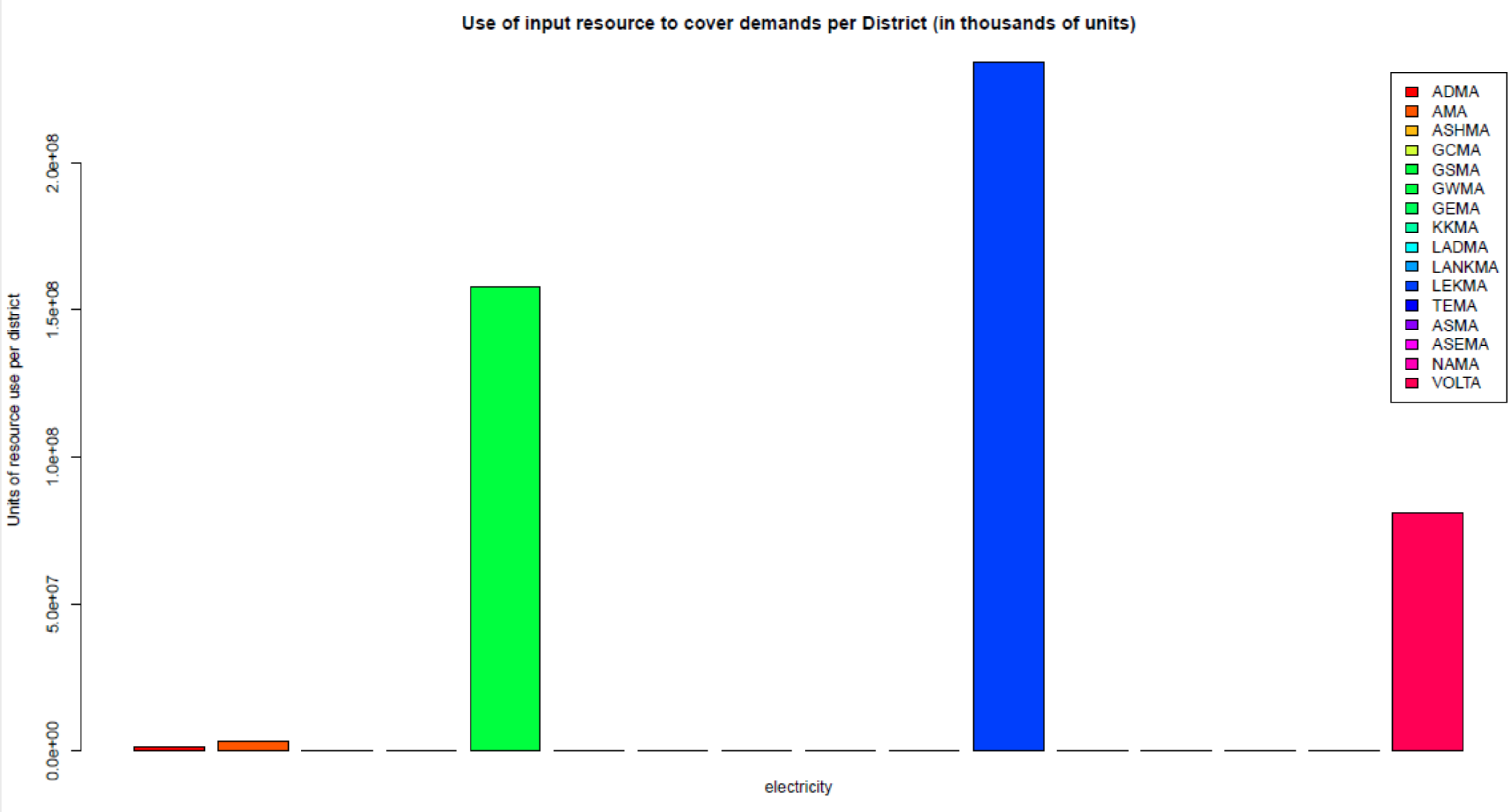


Figure 2.7 – Model generated graph of electricity use to cover water treatment in MJ in the **Central Pipe Scenario** in 2030

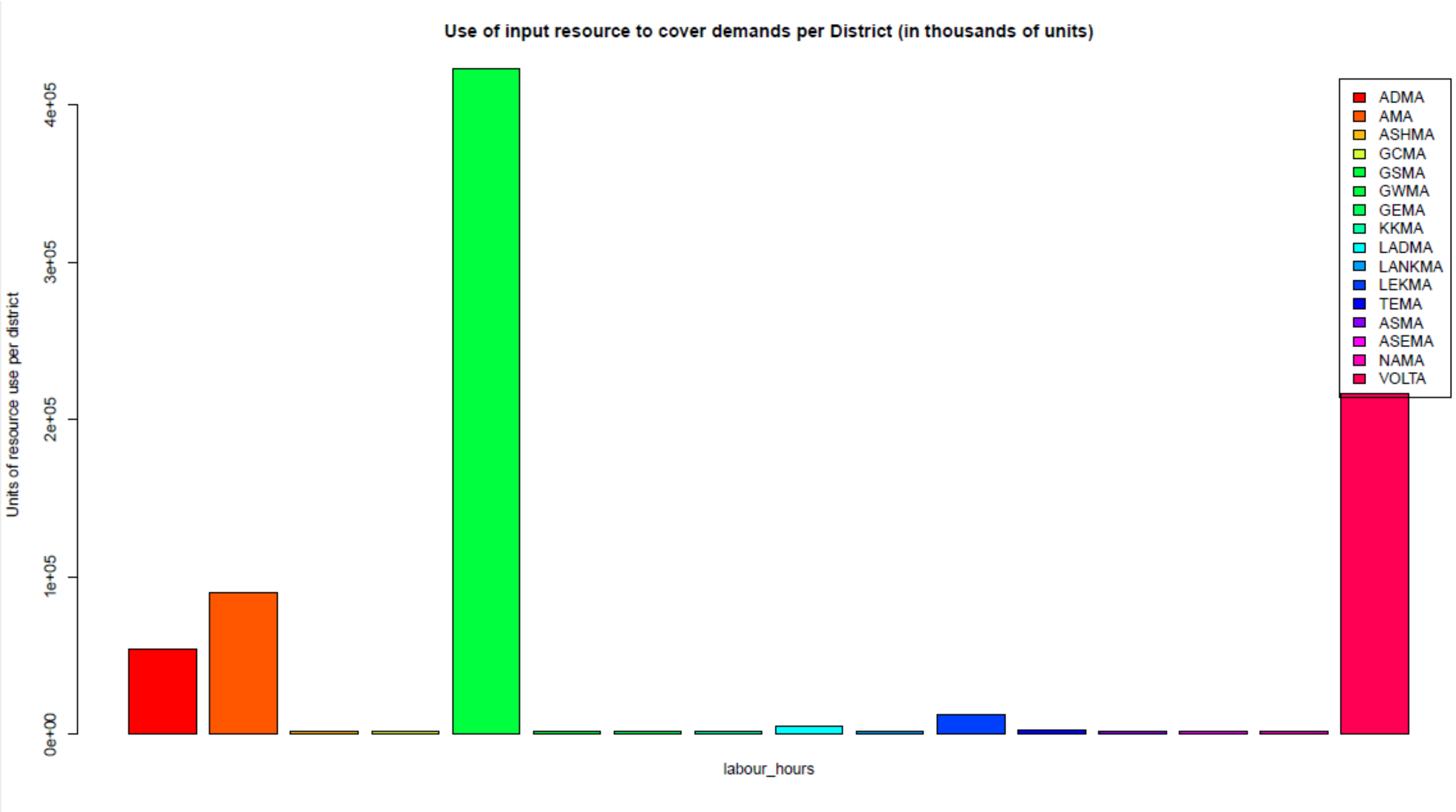


Figure 2.8 – Model generated graph of labour hour use to cover water treatment in MJ in the **Central Pipe Scenario** in 2030

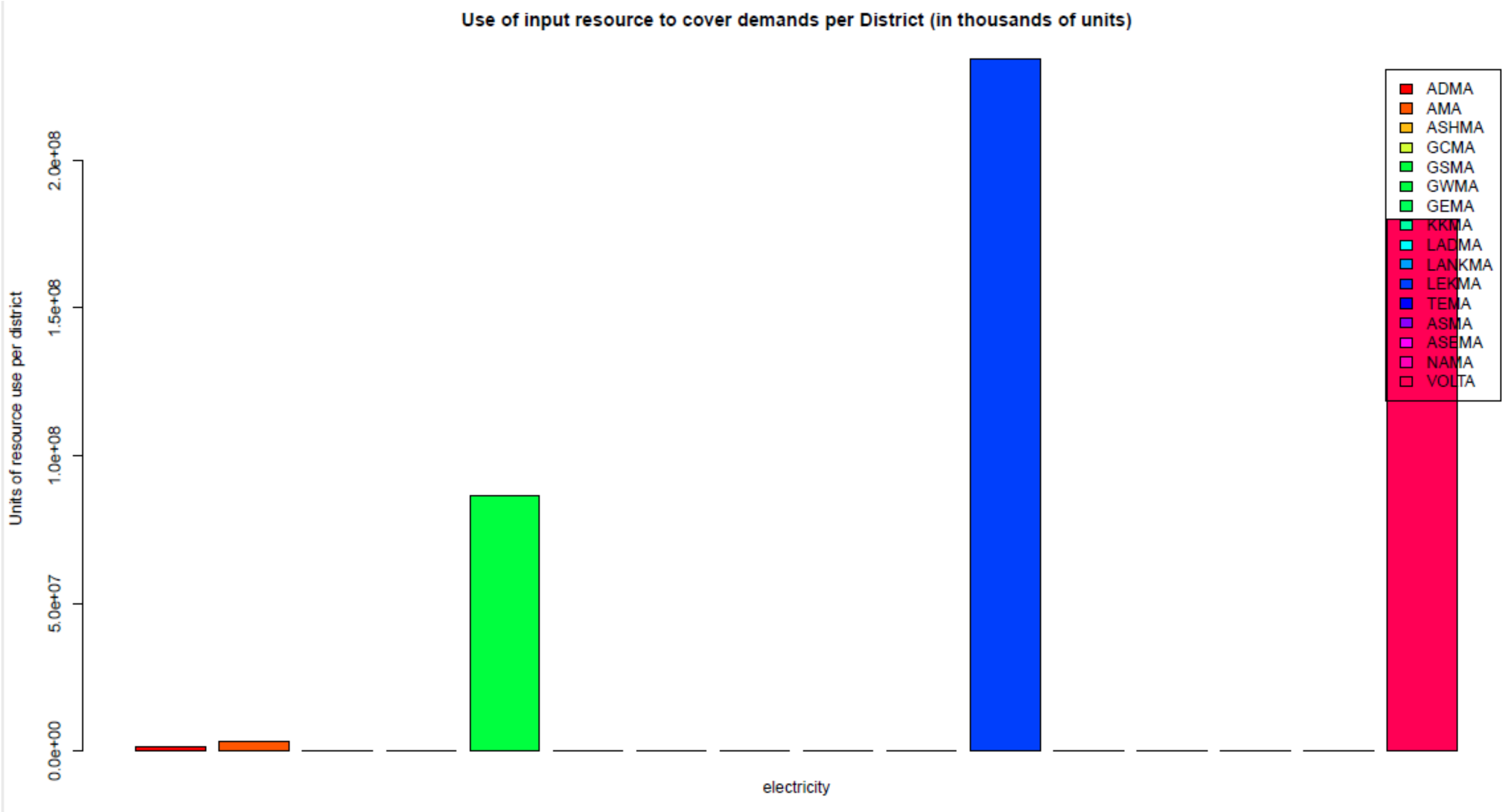


Figure 2.9 – Model generated graph of electricity use to cover water treatment in MJ in the **Local Pipe Scenario** in 2030.

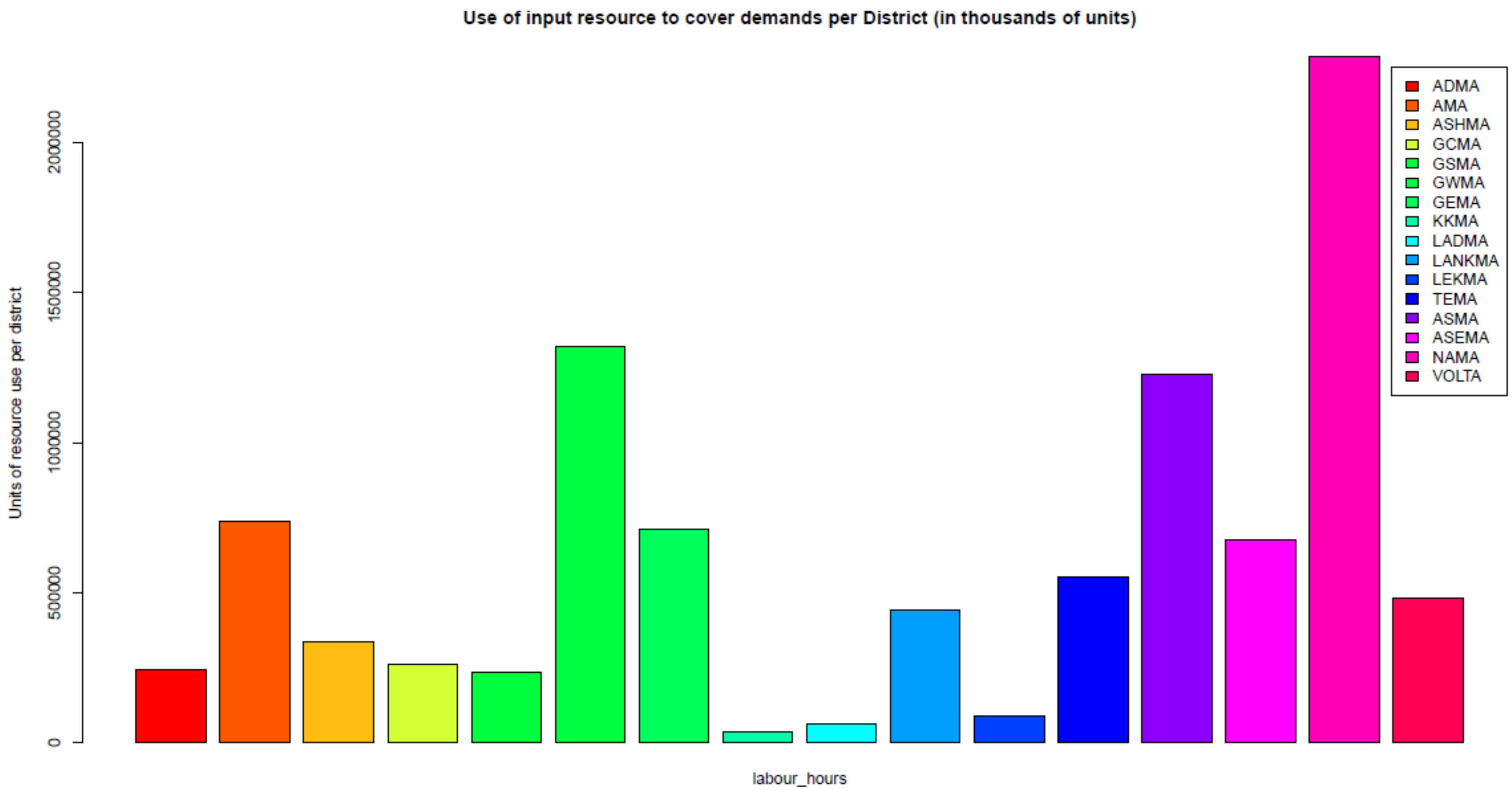


Figure 2.10 – Model generated graph of labour hour use to cover water treatment in MJ in the **Local Pipe Scenario** in 2030.

### 2.4.3 Results Pipeline Flows Comparison

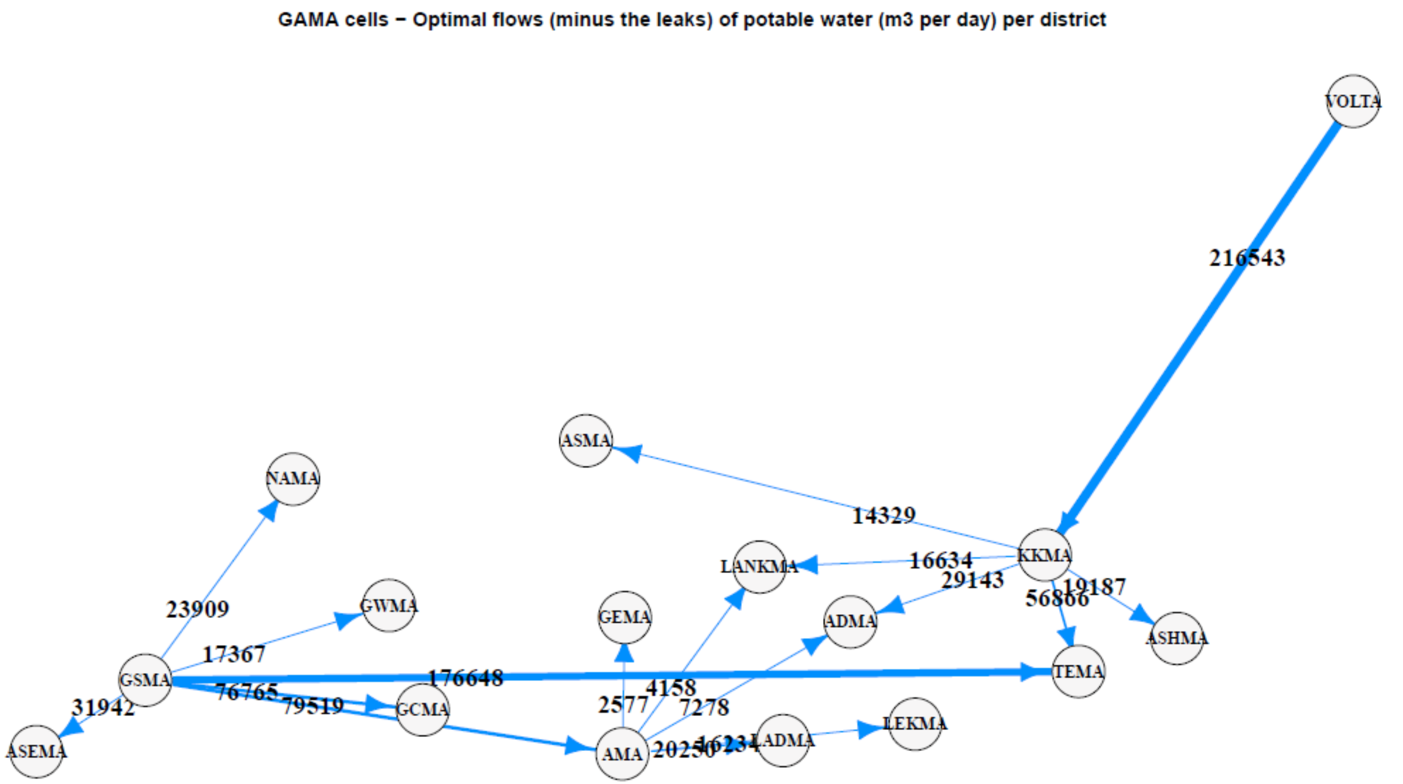


Figure 2.11 – Model generated graph of piped potable water flows per day in **the Central Pipe scenario** in 2030.

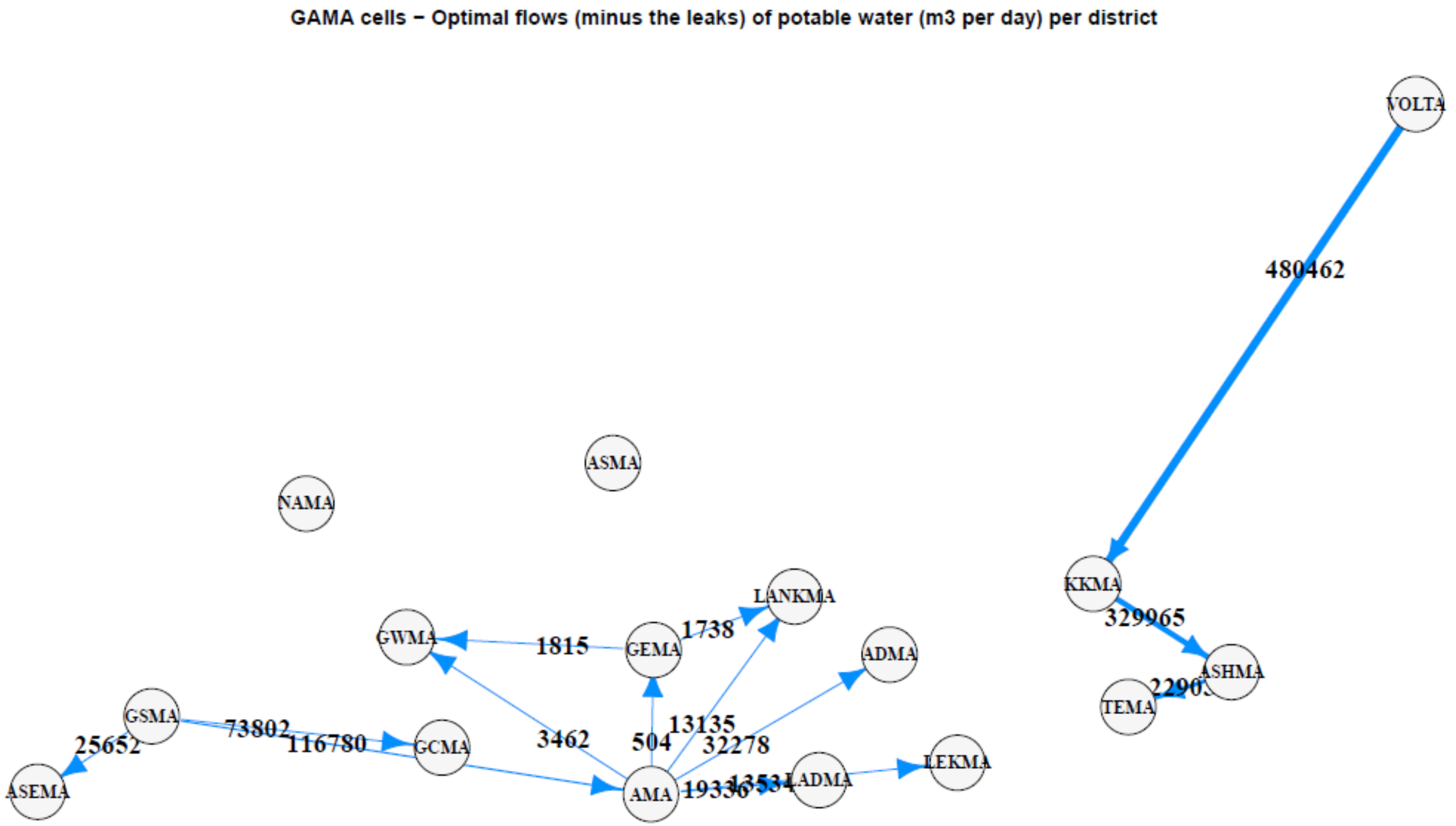


Figure 2.12 – Model generated graph of piped potable water flows per day in **the Local Pipe scenario** in 2030.

## 2.5 Discussion and Conclusions

The use case compared two approaches to meet 100% improved potable water demands in 2025. In the local pipe source scenario targets can be met by both central and local sources such as boreholes, improved wells, and springs. Whereas in the central pipe scenario targets were only allowed to be met by central water treatment excluding boreholes and improved wells and springs from being selected. Also for both scenarios a high population variant due to substantially larger immigration was calculated. The total difference in population for the GAMA city-region by 2025 is 5.68 million in the baseline and standard scenario versions, and 7.02 million people in the high immigration variants called “plus”.

In the central pipe system scenario the conventional water treatment at Weija and Kpong are expanded by a total of 633,000 $m^3$ per day. The additional capacity required to provide potable water to 1.3 million addition inhabitants is 229,500 $m^3$ per day in the “plus” version resulting in a total required additional capacity of 892,500 $m^3$ per day. The difference with the local pipe system is that only 510,000 $m^3$ per day is expanded, which is then complemented by 7,675 $m^3$ of additional boreholes and 40,094 $m^3$ per day of additional improved wells and springs capacity. The capacity is primarily utilised in districts which are currently not connected to the potable water pipe network, namely the Nsawam Adoagyiri (NAMA) and Akwapim South (ASMA) districts in the north. A substantially larger amount of central water treatment is built in the high immigration variant in this scenario, however, as the limited allowance of pipe expansion bars efficient division and flows of pipes in the city-region. As such there is a much larger amount of potable water leaked which necessitates much more capacity.

The sustainability of water drawn downs for the surface water sources of such expansions can be evaluated based on water influx into the waterbody, the amount of rainfall and the size of the waterbody, and evaporation. For example, the total amount of rainfall per year within GAMA is about 1675 mm per year. The surface area of lake Weija, for example is 33.6 $km^2$, which would translate to a rainfall influx of 15,500 m3 per day on average. However, direct lake rainfall is only a minor portion with influxes from the connected river system being significantly more important. A more detailed calculation including all components was made for this lake by Kuma and Ashley (2008).They found that rainfall and evaporation was about equal for Lake Weija under warm weather conditions. The main source was runoff from the reservoir was larger than abstraction of water by the treatment plant, and at rates at the time sustainable. The influx was also increasing over time alongside abstraction, since these are dynamic linked systems.

Also evaluated was the impact of leakage. The total amount of water leaked in 2025 in the local pipe scenario is 269,122 $m^3$ per day, versus 537,546 $m^3$ per day in the "local pipe source plus" scenario. In comparison the leakage in the "central pipe" and "central pipe source plus" scenario is 281,241 and 309,247 $m^3$ per day, respectively. The total increase in leakage in the "local pipe source plus" scenario results in a required 1,045,500 $m^3$ per day of conventional water treatment.

The total investment costs for the local pipe and central pipe source baseline variants are 0.98 million and 1.18 billion USD by 2025, respectively, so as to meet 100% improved potable water demand. The difference becomes substantially larger in the "plus" variants, where a total cost of 2.15 billion USD in the "local pipe plus" version, and the 1.65 billion USD in the "central pipe plus" version. Also the operational costs are lower in the central pipe version, with a total cost of 81 million USD per year by 2025, versus in the local pipe version 91 million USD. The increase in cost is only limited in the "central pipe source plus" version at 94 million USD per year by 2025 versus a total of 126 million USD in the "local pipe source plus" variant.

The affordability of the operational cost via incoming revenues in the baseline case of both scenarios by 2025 is sufficient. The total net surplus is 9.3 million USD in the local pipe versus 19.3 million USD in the central pipe scenario. The additional costs due to pipe losses in the "plus" variants leads to a negative sum of -2.1 million USD per year versus a positive 29.9 million USD by 2025 in the "central pipe source plus" scenario, however. Therefore on all financial accounts, and also taking into account higher immigration, the central pipe scenario is preferable over local sourcing for districts currently not connected to the pipe network. When translated to the total cost per inhabitant in the city per year, also taking into account population growth, the values are favourable. In the baseline scenario the costs for 2015 were estimated at 24.5 USD per year to provide potable water. These costs are reduced per person to 16 USD per person per year in the local pipe scenario, and 13 USD per person per year in the central pipe scenario. The implementation should therefore from an operational cost perspective improve the socio-economic situation of people, as less needs to be charged for water on average.

Jobs were found to increase substantially in the decentralized district scenario, whilst they increased on a limited basis in the city-wide systems situation. This is because the decentralized borehole technology for potable water utilizes a lot of labour to maintain each borehole, when done adequately. Total jobs varied substantially in time from the baseline 2015 level of 3081 for all potable water treatment. The changes for the local pipe system were an increase to 4173 jobs by 2025, versus a decrease to 370 jobs for the central pipe system. The main cause is the inclusion that all decentralized sources, including boreholes, are forcefully removed in central pipe scenario as part of the scenario. Since central treatment requires much less jobs this scenario is less positive from a job creation perspective. It would be relevant if a transition to increasing centralized potable water is undertaken, to take into account the number of jobs lost in boreholes operation and maintenance and potential alternative employment for these operators. .

The environmental changes of 100% improved potable water was captured by calculating the total GHG emissions of the WASH systems. On overall they increase from around 3800 tonnes in 2015 to 5432 tonnes in 2025 for central pipe and 4941 tonnes per year in the local pipe scenarios. The current situation is fairly low, and the increase is relatively minor when looking at these values relative to waste-water treatment, and so does not form a large factor or burden on GHG emissions for GAMA as a whole. These values could change substantially, however, if other sources of power then primarily hydro-power would be utilised, such as coal, oil, natural gas. The latter only forms a relatively minor input into the electricity system in GAMA. The effect of environmental change was further evaluated for sachet water plastics. Every cubic meter of sachet water results in about 7.7 kilogram of HDPE plastic waste for the sachet itself, and another 0.6 kg for the transport packaging plastics. Based on the initial rate of sachet use and if this would continue to grow at similar rates, the total daily waste of plastics from sachet water was estimated at 116 tonnes per day in 2015, which grows to 153 tonnes per day in 2025. In case of the high-immigration scenario the value is substantially higher at 122 tonnes to 180 tonnes per day from 2015 to 2025. By providing adequate improved water sourcing due to which sachets would no longer be necessary from an infrastructure and safety point of view, an annual amount of plastic waste around 42,000 to 45,000 tonnes that ends up in the environment can be saved.

## References

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GAMA FCA Ref. Group, 2015. *Definition of Greater Accra Metropolitan Area (unpublished)*,

Kuma, J., Ashley, D., 2008. *Runoff estimates into the Weija reservoir and its implications for water supply to Accra, Ghana. Journal of Urban and Environmental Engineering. 2 (2) pp. 33-40.*

Ministry of Water Resources Works and Housing and MInistry of Local Government and Rural Development, 2012. *National Strategy for Community Participation in Management of Urban Wash Services*,

Twum-Baah, K.A. et al., 2005. *2000 Population and Housing Census: Greater Accra Region Analysis of District Data and Implications for Planning*, Accra.

# resilience.io Use Case 3: Increase availability of clean, accessible, and affordable toilet infrastructure



| | |
|---|---|
| **Created:** | May 2016 |
| **Authors:** | Rembrandt Koppelaar (IIER), Xiaonan Wang (ICL), Koen van Dam (ICL), Harry Triantafyllidis (ICL), Hannes Kunz (IIER), Nilay Shah (ICL) |



## 3.1 Overview

The capital city of Ghana and its neighbouring administrative districts form the Greater Accra Metropolitan Area (GAMA). A rapidly growing metropolitan region where efforts to improve the water, sanitation, and hygiene (WASH) situation have yielded mixed results. Household access to piped water grew by 81% to 83% from 2000 to 2010 and access to public and private improved toilet facilities increased from 58% to 81% (Twum-Baah et al. 2005; Bentsi-Enchill et al. 2013). However, the percentage of total wastewater treated, including human excreta, declined from around 10% to near zero between 2000 and 2010, whilst the population of GAMA grew from 3 to 4 million people.

The use case serves to support the Metropolitan and Municipal District Assemblies (MMDA) to design and appraise the costs of toilets within criteria of financial sustainability, accessibility and hygiene. As well as assess different means to treat the faecal sludge produced in toilet systems from a financial and environmental perspective. The use case relates to the policy planning in the National Environmental Sanitation Strategy and Action Plan and the Revised Environmental Sanitation Policy, as developed by the Environmental Sanitation Unit by the Ministry of Local Government and Rural Development (GoG MLGRD 2010a; GoG MLGRD 2010b).

The focus in the use case lies on understanding how the toilet and faecal sludge treatment infrastructure needs could evolve depending on different socio-economic population scenarios within GAMA, including population growth and migratory developments. The geographic boundary definition of GAMA as a city region used in the use case was defined by local stakeholders using the Metropolitan and Municipal District Assembly (MMDA) structures in the country (GAMA FCA Ref. Group 2015). The definition includes 15 districts, with the Accra and Tema Metropolitan districts as the most populous and with the majority of economic activity. The calculations are carried out at both the individual MMDA level, and aggregated to GAMA in the results, in line with and in support of the development of District Medium Term Development Plans (DMTDP).

The use case is described in section 3.2. The calculation functionality and scenarios provided by resilience.io to support policy inputs is described in section 3.3. The results of the use case scenario runs are visually provided in section 3.4. Finally, conclusions from the use case are summarised in section 3.5 below.

## 3.2 Use Case Description

The access to toilet infrastructure within the Greater Accra Metropolitan Area remains a significant challenge. It has been estimated that over 5,000 pan (bucket) latrines in GAMA are still used, out of about 20,000 country-wide, despite the public ban of using such infrastructure. The use of public toilets is estimated to be prevalent with 30% of households relying on various types such as WCs, KVIPs and Aqua Privies. A substantial number of residents in parts of GAMA express complaints about unaffordable or lack of private toilet infrastructure, as well as inadequate public toilets resulting in large queues, and unsanitary open defecation practices.

The increase in toilets and reduction in open defeacation has been promoted by various means varying by MMDA. Both by adding public toilets from MMDA financing, by private market provided public toilets, obliging home-owners and developers to install private toilets, and fining people who defecate in the open. A challenge is the rapid urban development and informal settlement structure, which makes it difficult to provide adequate toilets at sufficient distance. The finance of toilets and related infrastructure, the affordability of public toilet usage, and the limited space in the densely populated areas that is prioritised for living instead of toilet placement by developers/home-owners.

The aim of the use case is to add to these efforts by providing functionality for the MMDAs' water and sanitation units and communities to appraise different solutions to improve sanitation. The following functionalities of the prototype are tested within the use case:

- The calculation of faecal sludge output from toilet usage per district within GAMA by the population based on a range of input parameter assumptions.
- The exploration of what treatment infrastructure for faecal sludge is best suitable from a lowest cost and environmental perspective, both from a standalone system perspective and as part of larger waste-water treatment systems.
- The estimation of the number of public and/or private toilets required to provide for accessible toilet usage within the territory of each district, based on a % toilet access target of the population.
- The evaluation of the cost of toilet usage and affordability thereof, based on the tariffs for public toilet usage and wastewater sewerage tariffs.

The outcomes are calculated on the basis of a number of input values which are described in the following section on scenarios.

## 3.3 Scenarios for third use case

A total of four scenarios are calculated within the use case to demonstrate how the changes in the population affect toilet use requirements, and the treatment needs for faecal sludge from toilets. The use case utilises a baseline scenario which calculates the current situation and development from current projects.

The four scenarios include:

- **Baseline scenario**, wherein the 2010 utilisation of private and public toilet infrastructure is estimated and the generation of faecal sludge from these toilets. In the scenario population changes to 2030 are estimated including unmet demands and changes in improved and unimproved toilet access given current projects and natural expansion.
- **Public toilet access and decentralised treatment,** where the assumption is that toilet demands will continue to be met for a significant part via public infrastructure. In the scenario it is assessed what technology and infrastructure can be utilised at the best cost to locally treat toilet outputs within a district.
- **Private toilet access and centralised treatment,** where the assumption is that toilet demands will increasingly be met via private infrastructure. And that this infrastructure is linked to a central waste-water pipe system and treatment capacity.
- **Decentralised biogas and charcoal briquettes,** where the public toilet scenario was taken and on top a new technology capabilities were introduced to produce biogas from faecal sludge as well as charcoal briquettes from the solid component. The value of the biogas and charcoal briquettes in the flow of public toilet faecal sludge collection to treatment to biogas system can subsequently be estimated.

The outcomes are calculated on the basis of a substantial number of input values. The baseline scenario is based on similar population value outcomes as in the baseline described in section 1.3.1. The additional parameter settings for the other scenarios are provided in the following subsections prior to the description of results in section 3.4.

### 3.3.1 Base-line scenario

In the base-line scenario demographic changes of the population are first calculated. These form inputs to estimate water demands, generated wastewater, and faecal sludge to be treated over time. Based on existing toilet infrastructures the percentage of satisfied needs is calculated for every five year interval.

To estimate the additional toilets which need to be constructed to meet toilet demands the distribution and capacities for the baseline year 2010 were estimated. In the absence of data about the current amount of toilet facilities, an estimation was made based on the population and their access/use of sanitation infrastructure with data from the Ghana Statistical Service, as shown in Table 3.1 below. The total population is categorized to subgroups that have access to different toilet types (W.C., Public Toilet, Bucket/Pan, Kumasi VIP, Pit Latrine, No Facilities).

*Table 3.1 – Existing toilets and access in base-year scenario 2010*

| Type | Total use times | Total numbers | No. for Female | No. for Male |
|---|---|---|---|---|
| **Public Toilet** | 1,274,608 | 3,983 | 2,109 | 1,874 |
| **WC** | 1,253,251 | 250,650 | 127,606 | 123,044 |
| **Pit Latrine** | 398,381 | 27,072 | 14,353 | 12,719 |
| **Kumasi VIP** | 600,787 | 9,387 | 4,908 | 4,479 |
| **No Facilities*** | 355,540 | 280,547 | 150,610 | 129,937 |

*Includes bucket/pan latrines

To estimate the capacity of each toilet types it was estimated that WC's are used privately, so that each one can support a family of 5 people. The total number of WC's is thereby evaluated to be 250,650. In case of public toilets it was assumed that these are used by 320 people on a daily basis. Similarly it is assumed each pit latrine or Kumasi VIP is shared by 64 people. The rest of populations have no access to improved facilities and may choose to use open defecation or an illegal bucket/pan latrine. The estimated evolution of toilet facilities in the base-line scenario is shown in table 3.2 below.

*Table 3.2 – Number of different toilet facilities estimated in base-line scenario for 2015-2030*

| Type | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|
| **Public Toilet** | 4,665 | 5,489 | 6,485 | 7,693 |
| **WC** | 310,841 | 387,256 | 484,400 | 608,086 |
| **Pit Latrine** | 7,657 | 9,482 | 11,799 | 14,748 |
| **Kumasi VIP** | 11,507 | 14,230 | 17,717 | 22,186 |

### 3.3.2 Public toilet and decentralised treatment scenario

In comparison with the base-line scenario with no specific construction of treatment capacities, in this scenario it is assumed that toilet use is expanded by constructing additional public toilets. These are within a district connected to local waste-water treatment. To this end the amount of additional waste-water expansions are limited to zero, which could otherwise also be utilised for faecal sludge for transport to treatment sites, as shown in table 3.3 below.

*Table 3.3 – Allowable district waste-water connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| District | District | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA |
| ADENTA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ACCRA_METROPOLITAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ASHAIMAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_CENTRAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_WEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| KPONE_KATAMANSO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LA_DADE_KOTOPON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LA_NKWANTANANG_MADINA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LEDZOKUKU_KROWOR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TEMA_METROPOLITAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AKWAPIM_SOUTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AWUTU_SENYA_EAST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NSAWAM_ADOAGYIRI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 3.3.3 Private toilet and centralised treatment scenario

The scenario assumes that toilet use is expanded by constructing additional private toilets and creating a sewerage network within the city between districts, so as to transport faecal sludge to a central treatment site. To this end all waste-water expansions are allowed as shown in table 3.4 below, and a number of central faecal sludge treatment plants are built in AMA, TEMA, and Ga West

The plants built on-top of on-going projects by 2020 as set by the user include a 1000 m3 per day septage treatment plant at TEMA, and another 1000 m3 per day UASB septage treatment plant in Ga West.

*Table 3.4 – Allowable district waste-water connections in scenario from 2020 onwards from/to with a capacity of 1800 m3 per hour*

| District \ District | ADMA | AMA | ASHMA | GCMA | GSMA | GWMA | GEMA | KKMA | LADMA | LANKMA | LEKMA | TEMA | ASMA | ASEMA | NAMA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADENTA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ACCRA_METROPOLITAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ASHAIMAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| GA_CENTRAL | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| GA_SOUTH | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GA_WEST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| GA_EAST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| KPONE_KATAMANSO | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LA_DADE_KOTOPON | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LA_NKWANTANANG_MADINA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LEDZOKUKU_KROWOR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TEMA_METROPOLITAN | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AKWAPIM_SOUTH | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AWUTU_SENYA_EAST | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| NSAWAM_ADOAGYIRI | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

### 3.3.4 Decentralised biogas and charcoal briquettes scenario

In the scenario the methane produced by the central waste-water treatment plant, UASB septage plants, and decentralized anaerobic biogas digesters is all assumed to be captured and put on sale on the market. Similarly, the dry component of the faecal sludge polymer separation drying plants are as already the case assumed to be converted into charcoal briquettes, which can then be sold on the market. The scenario is otherwise similar to the public toilet and decentralized treatment scenario. By adding these changes the value of biogas and charcoal to the WASH system can be evaluated and taken into consideration.

## 3.4 Results Overview

*Table 3.5 – Results comparison for 3rd use case toilet access plus infrastructure change*

| | Year | Baseline | Private toilets and central system | Public toilets and decentralised systems | Decentralised Biogas Production |
|---|---|---|---|---|---|
| **Improved toilets % access**[1] | 2015 | 80.5% | 85% | 85% | 85% |
| | 2020 | 80.4% | 90% | 90% | 90% |
| | 2025 | 80.2% | 100% | 100% | 100% |
| | 2030 | 80.0% | 100% | 100% | 100% |
| **Total GAMA Population (millions)** | 2015 | 4.39 | 4.39 | 4.39 | 4.39 |
| | 2020 | 4.98 | 4.98 | 4.98 | 4.98 |
| | 2025 | 5.68 | 5.68 | 5.68 | 5.68 |
| | 2030 | 6.49 | 6.49 | 6.49 | 6.49 |
| **Total GAMA Faecal Sludge Generated (m3 per day)**[2] | 2015 | 6651 | 6651 | 6651 | 6651 |
| | 2020 | 7614 | 7614 | 7614 | 7614 |
| | 2025 | 8708 | 8708 | 8708 | 8708 |
| | 2030 | 9975 | 9975 | 9975 | 9975 |
| **Additional district-to-district waste-water pipe connection including faecal sludge in no.** | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 12 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 |
| **Additional private toilets in no.** | 2010-2015 | 60,190 | 102,680 | 0 | 0 |
| | 2015-2020 | 76,416 | 144,530 | 0 | 0 |
| | 2020-2025 | 97,143 | 264,689 | 0 | 0 |
| | 2025-2030 | 123,687 | 191,243 | 0 | 0 |
| **Additional public toilets in no.** | 2010-2015 | 682 | 0 | 1346 | 1346 |
| | 2015-2020 | 824 | 0 | 2011 | 2011 |
| | 2020-2025 | 996 | 0 | 4158 | 4158 |
| | 2025-2030 | 1208 | 0 | 2264 | 2264 |
| **Additional Central Waste Water Treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 694,450 | 16,150 | 16,150 |
| | 2020-2025 | 0 | 161,500 | 0 | 0 |
| | 2025-2030 | 0 | 48,450 | 0 | 0 |
| **Additional Aerated Lagoon Treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 539,325 | 539,325 |
| | 2020-2025 | 0 | 0 | 79,900 | 82,900 |
| | 2025-2030 | 0 | 0 | 39,950 | 39,950 |
| | 2010-2015 | 0 | 0 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| **Additional decentralised Activated Sludge capacity (m3 per day)** | 2015-2020 | 0 | 0 | 126,539 | 26,592 |
| | 2020-2025 | 0 | 0 | 13,754 | 13,754 |
| | 2025-2030 | 0 | 0 | 27,509 | 27,509 |
| **Additional decentralised faecal sludge polymer separation drying plant capacity (m3 per day)** | 2010-2015 | 0 | 8,424 | 6,413 | 6,413 |
| | 2015-2020 | 0 | 3,563 | 2,138 | 1,425 |
| | 2020-2025 | 0 | 0 | 1,425 | 1,425 |
| | 2025-2030 | 0 | 0 | 1,425 | 1,425 |
| **Additional small scale anaerobic biogas treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 1,231 |
| | 2020-2025 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 |
| **Additional small scale aerobic treatment plant capacity (m3 per day)** | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 |
| **Additional UASB Septage treatment plant with biogas System Capacity (m3 per day)** | 2010-2015 | 0 | 0 | 4,080 | 4,080 |
| | 2015-2020 | 0 | 0 | 0 | 0 |
| | 2020-2025 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 |

[1]Improved toilets include Public Toilet, WC and Kumasi VIP.

[2]Faecal Sludge Generated includes both sewage and sludge (1 cubic metre of sewage/sludge weights around 0.72 tonnes). Reference: N. N. Greenwood, A. Earnshaw. Chemistry of the Elements. Butterworth – Heinemann, 1997.

*Table 3.6 – Results comparison for 3rd use case costs and revenues – all values in current 2015 dollars and not inflation corrected*

| | Year | Baseline | Private toilets and central system | Public toilets and decentralised systems | Decentralised Biogas Production |
|---|---|---|---|---|---|
| **Capital expenditure for on-going and completed faecal sludge projects on the ground since 2010 (billion USD)** | 2010-2015 | 0.028 | 0.028 | 0.028 | 0.028 |
| | 2015-2020 | 0.077 | 0.077 | 0.077 | 0.077 |
| | 2020-2025 | 0 | 0 | 0 | 0 |
| | 2025-2030 | 0 | 0 | 0 | 0 |
| **Capital expenditure for additional waste-water and faecal sludge treatment infrastructure per 5 years (billion USD)** | 2010-2015 | 0 | 0.02 | 0.09 | 0.09 |
| | 2015-2020 | 0 | 2.26 | 0.22 | 0.24 |
| | 2020-2025 | 0 | 0.54 | 0.04 | 0.03 |
| | 2025-2030 | 0 | 0.16 | 0.06 | 0.06 |
| | 2010-2015 | 0 | 0 | 0 | 0 |
| | 2015-2020 | 0 | 0.02 | 0 | 0 |
| | 2020-2025 | 0 | 0.005 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| **Of which capital expenditure for pipeline expansion waste-water and faecal sludge treatment (billion USD)** | 2025-2030 | 0 | 0 | 0 | 0 |
| **Capital expenditure for toilet construction * (million USD)** | 2010-2015 | 35.9 | 25 | 41.9 | 41.9 |
| | 2015-2020 | 44.2 | 35.1 | 62.7 | 62.7 |
| | 2020-2025 | 54.6 | 64.3 | 129.6 | 129.6 |
| | 2025-2030 | 67.7 | 46.5 | 70.6 | 70.6 |
| **Operational expenditure for infrastructure per year (million USD)** | 2015 | 55.6 | 56.3 | 58.2 | 58.2 |
| | 2020 | 63.6 | 41.4 | 69.3 | 69.1 |
| | 2025 | 73.2 | 47.6 | 80.5 | 80.6 |
| | 2030 | 84.3 | 54.4 | 92.1 | 92.2 |
| **Operational expenditure per inhabitant per year (USD)** | 2015 | 12.7 | 12.8 | 13.1 | 13.1 |
| | 2020 | 12.8 | 6.2 | 11.4 | 11.4 |
| | 2025 | 12.9 | 6.2 | 11.6 | 11.6 |
| | 2030 | 13.0 | 6.2 | 11.7 | 11.7 |
| **Operational expenditure spent on labour per year (million USD)** | 2015 | 0.05 | 0.07 | 0.6 | 0.6 |
| | 2020 | 0.40 | 7.4 | 2.7 | 2.7 |
| | 2025 | 0.40 | 8.6 | 3.1 | 3.1 |
| | 2030 | 0.40 | 9.8 | 3.5 | 3.5 |
| **Operational expenditure for electricity per year (million USD)** | 2015 | 0.02 | 0.01 | 0.07 | 0.07 |
| | 2020 | 0.14 | 3.3 | 9.7 | 9.7 |
| | 2025 | 0.14 | 3.8 | 11.3 | 11.4 |
| | 2030 | 0.14 | 4.3 | 12.9 | 13.0 |
| **Revenues from public toilet usage (million USD)** | 2015 | 33 | 0 | 38 | 38 |
| | 2020 | 39 | 0 | 52 | 52 |
| | 2025 | 46 | 0 | 82 | 82 |
| | 2030 | 55 | 0 | 98 | 98 |
| **Values of biogas produced in (million USD)** | 2015 | 0 | 0 | 0 | 0 |
| | 2020 | 0 | 0 | 0 | 0.58 |
| | 2025 | 0 | 0 | 0 | 0.58 |
| | 2030 | 0 | 0 | 0 | 0.59 |
| **Value of sludge based briquettes produced (million USD)** | 2015 | 0 | 0 | 0 | 0 |
| | 2020 | 0 | 0 | 0 | 4.23 |
| | 2025 | 0 | 0 | 0 | 4.72 |
| | 2030 | 0 | 0 | 0 | 5.75 |

*Table 3.7 – Results comparison for 3st use case environment, energy and labour*

| | Year | Baseline | Private toilets and central system | Public toilets and decentralised systems | Decentralised Biogas Production |
|---|---|---|---|---|---|
| | 2015 | 1,776 | 1,776 | 1,776 | 1,776 |

| | | | | | |
|---|---|---|---|---|---|
| **Total GHG emissions in tonnes for faecal sludge treatment** | 2020 | 2,011 | 6,926 | 6,926 | 6,926 |
| | 2025 | 2,011 | 7,516 | 7,516 | 7,516 |
| | 2030 | 2,011 | 8,547 | 8,547 | 8,547 |
| **GHG emissions in kg per m3 for faecal sludge treatment** | 2015 | 108 | 78 | 76 | 76 |
| | 2020 | 61 | 16 | 215 | 215 |
| | 2025 | 61 | 15 | 219 | 219 |
| | 2030 | 61 | 15 | 217 | 217 |
| **Total electricity use in kWh for waste-water+ faecal sludge treatment plus collection** | 2015 | 217,500 | 236,232 | 920,192 | 920,192 |
| | 2020 | 2,005,675 | 45,374,266 | 134,449,127 | 136,438,245 |
| | 2025 | 2,005,675 | 57,752,152 | 157,195,312 | 159,204,368 |
| | 2030 | 2,005,675 | 60,414,749 | 179,380,354 | 183,426,893 |
| **Electricity use in kWh per m3 for wastewater + aecal sludge treatment plus collection** | 2015 | 13.2 | 10.4 | 11.3 | 11.3 |
| | 2020 | 60.8 | 104.7 | 364.0 | 369.4 |
| | 2025 | 60.8 | 105.7 | 370.8 | 375.4 |
| | 2030 | 60.8 | 105.8 | 369.2 | 377.0 |
| **Total jobs in number for faecal sludge treatment plus collection and public toilets** | 2015 | 161 | 161 | 161 | 161 |
| | 2020 | 232 | 1510 | 545 | 557 |
| | 2025 | 232 | 1753 | 625 | 632 |
| | 2030 | 232 | 2006 | 711 | 724 |
| **Labour hours in number for faecal sludge treatment plus collection and public toilets** | 2015 | 22,511 | 27,988 | 263,195 | 263,195 |
| | 2020 | 166,417 | 3,080,862 | 1,111,826 | 1,136,280 |
| | 2025 | 166,417 | 3,575,647 | 1,275,550 | 1,289,280 |
| | 2030 | 166,417 | 4,091,261 | 1,449,790 | 1,476,960 |
| **Labour hours in no per m3 for faecal sludge treatment plus collection and public toilets** | 2015 | 1.36 | 1.23 | 11.3 | 11.3 |
| | 2020 | 5.04 | 7.11 | 3.0 | 3.0 |
| | 2025 | 5.04 | 7.16 | 3.0 | 3.0 |
| | 2030 | 5.04 | 7.16 | 3.0 | 3.0 |
| **Total biogas produced in million m3 per year** | 2015 | 0 | 0 | 0 | 0 |
| | 2020 | 0 | 0 | 0 | 2.88 |
| | 2025 | 0 | 0 | 0 | 2.91 |
| | 2030 | 0 | 0 | 0 | 2.95 |
| **Total sludge based briquettes produced in tonnes per year** | 2015 | 0 | 0 | 0 | 34,500 |
| | 2020 | 0 | 0 | 0 | 42,300 |
| | 2025 | 0 | 0 | 0 | 47,166 |
| | 2030 | 0 | 0 | 0 | 57,475 |

### 3.4.1 Results District values for Waste-water and Faecal Sludge Treatment Capacity

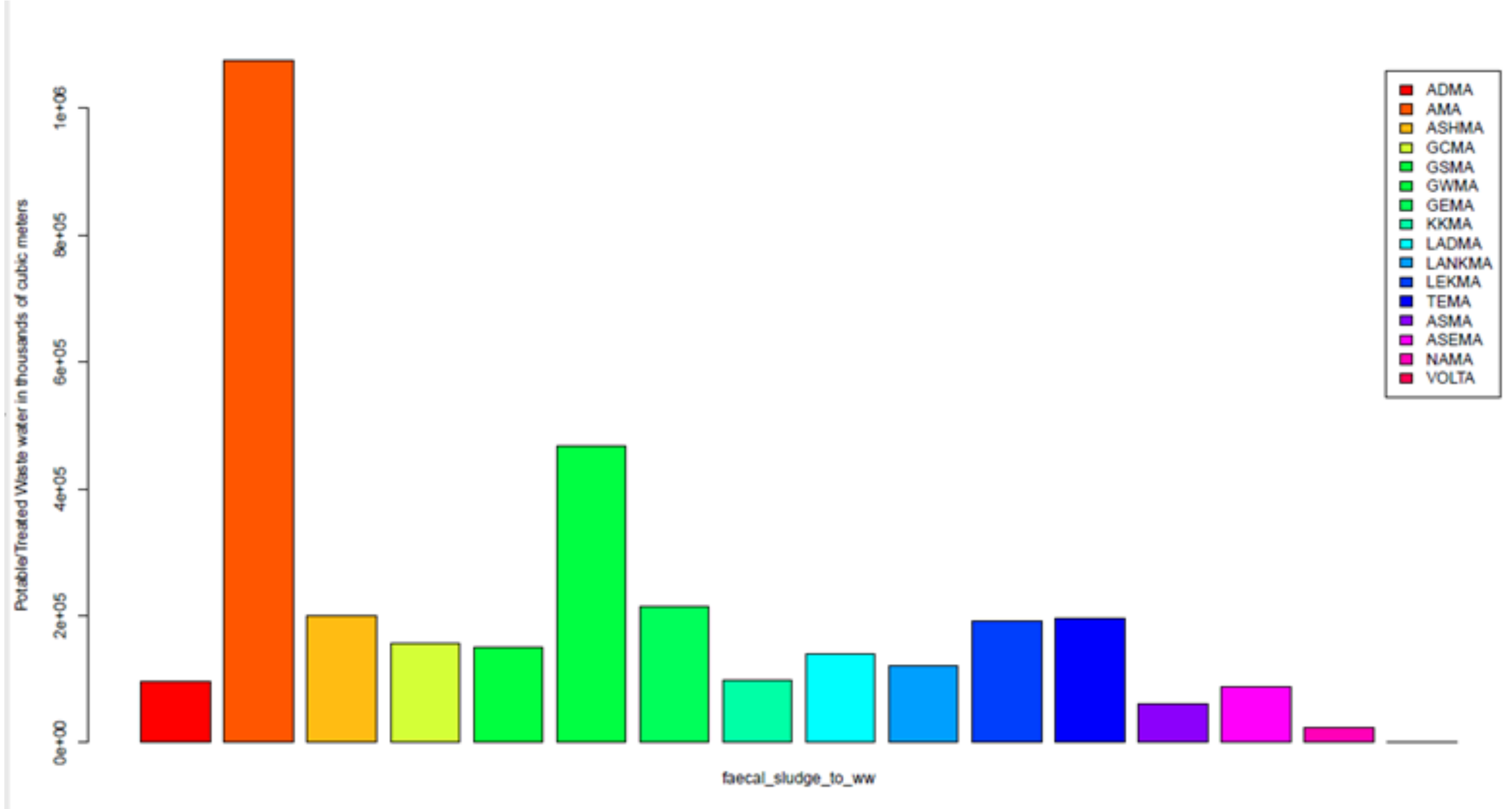


Figure 3.1 – Model generated graph for amounts of faecal sludge absorbed in the waste-water flows for centralised treatment in the **Central Private Toilet Scenario** in 2030.

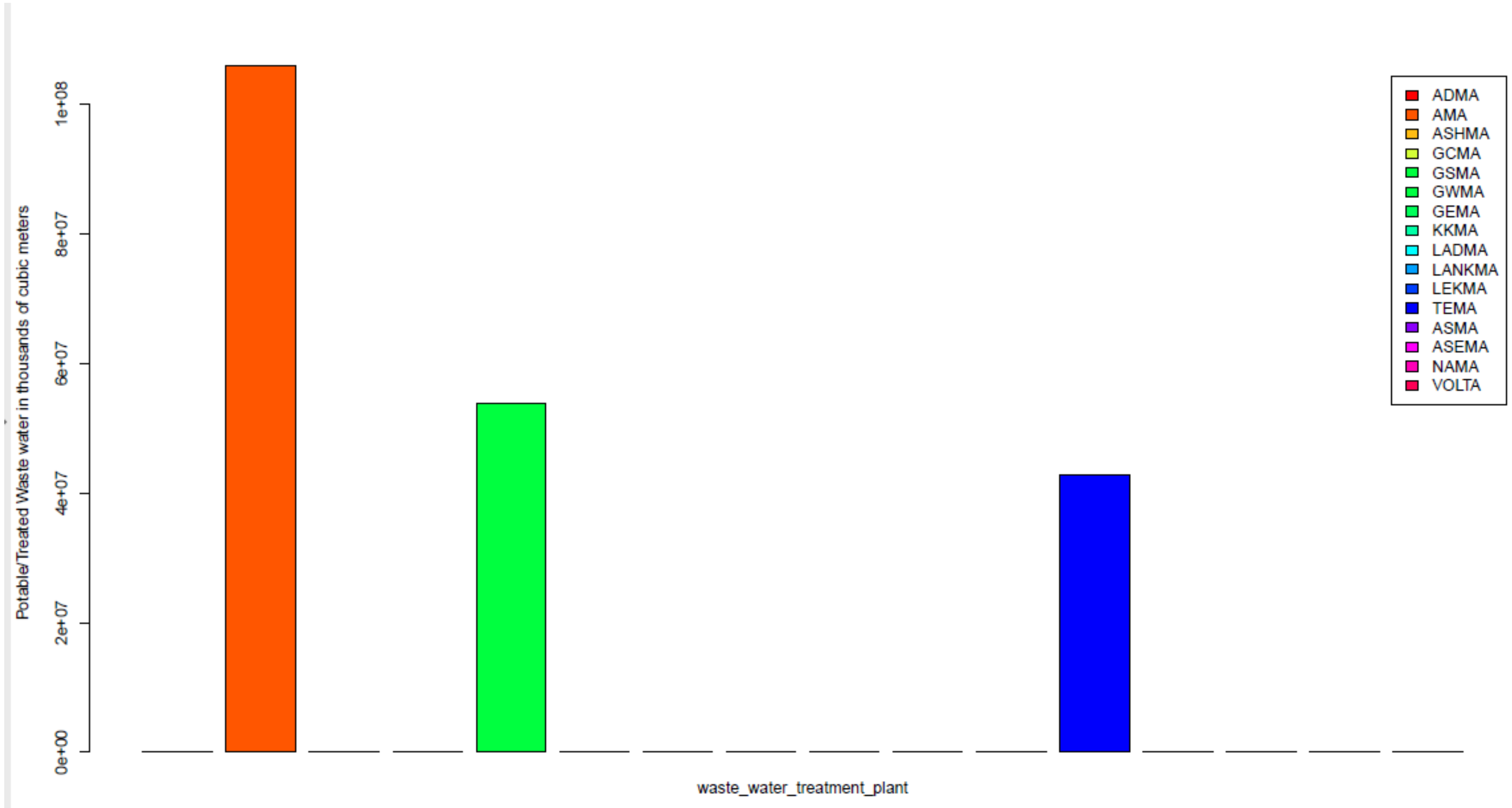


Figure 3.2 – Model generated graph for production rates per year for conventional waste water treatment plants in the **Central Private Toilet Scenario** in 2030.

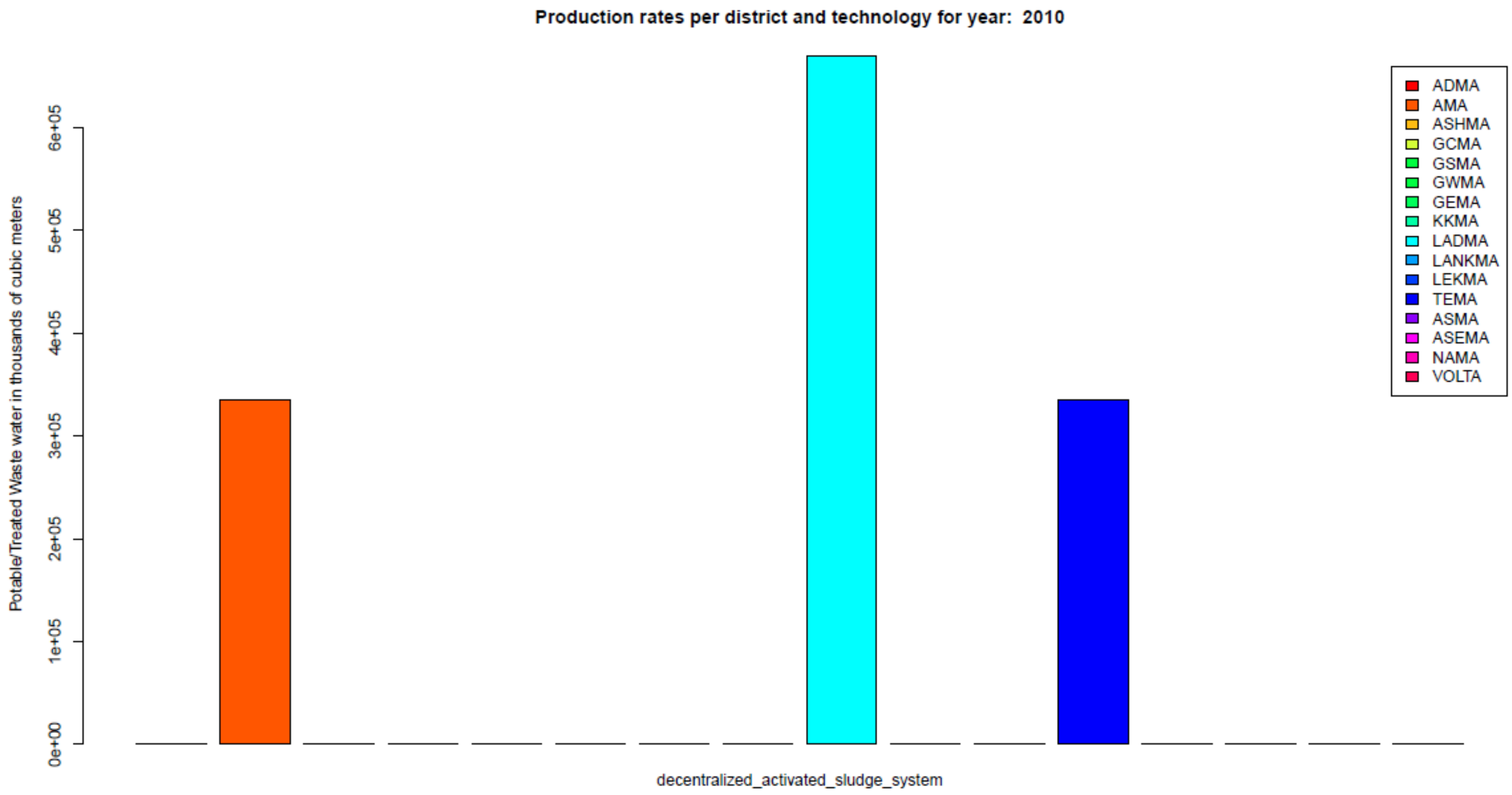


Figure 3.3 – Model generated graph for production rates per year for decentralised activated sludge treatment systems in the **Central Private Toilet Scenario** in 2030.

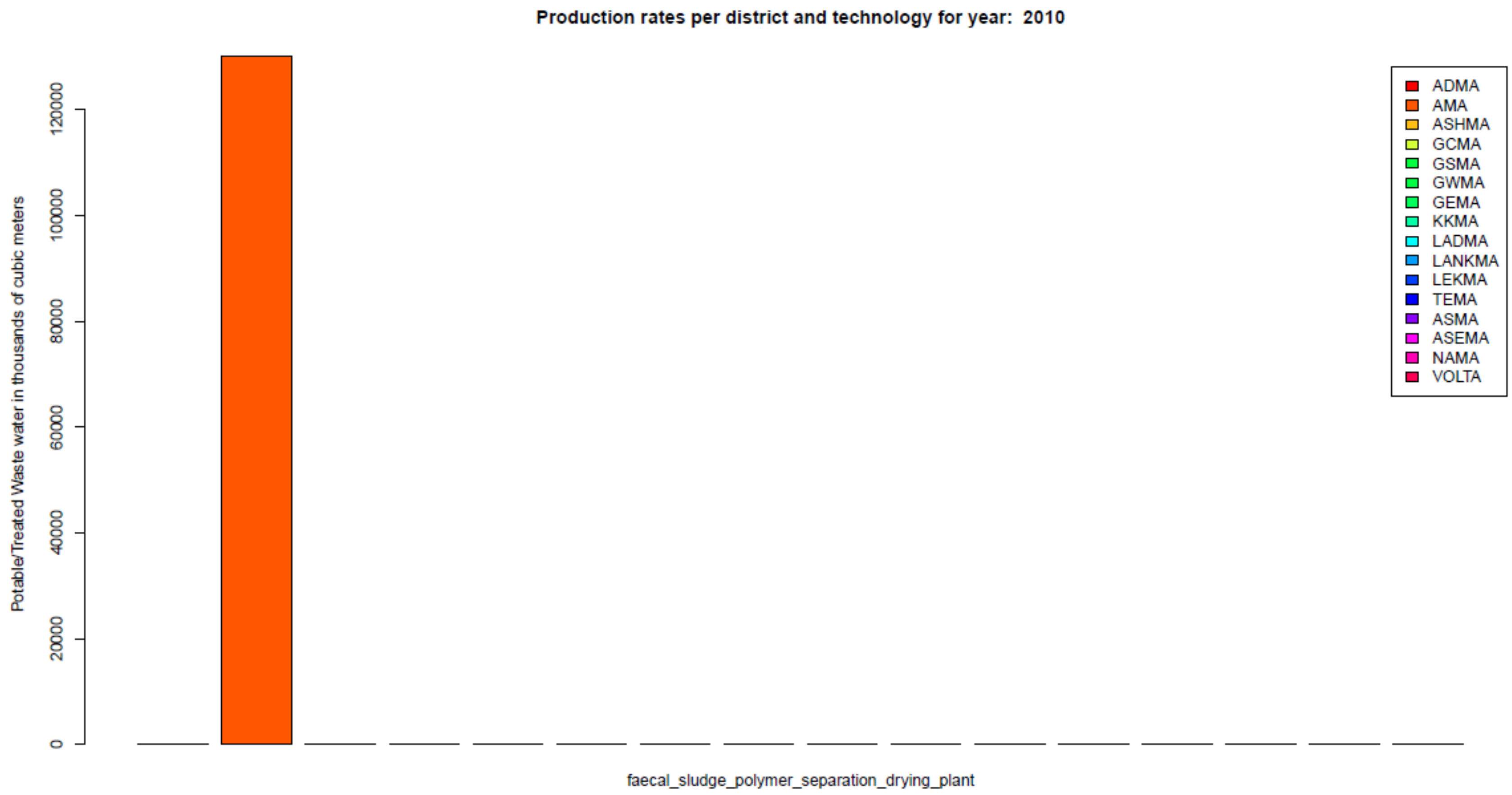


Figure 3.4 – Model generated graph for production rates per year for faecal sludge polymer separation and drying plants in the **Central Private Toilet Scenario** in 2030.

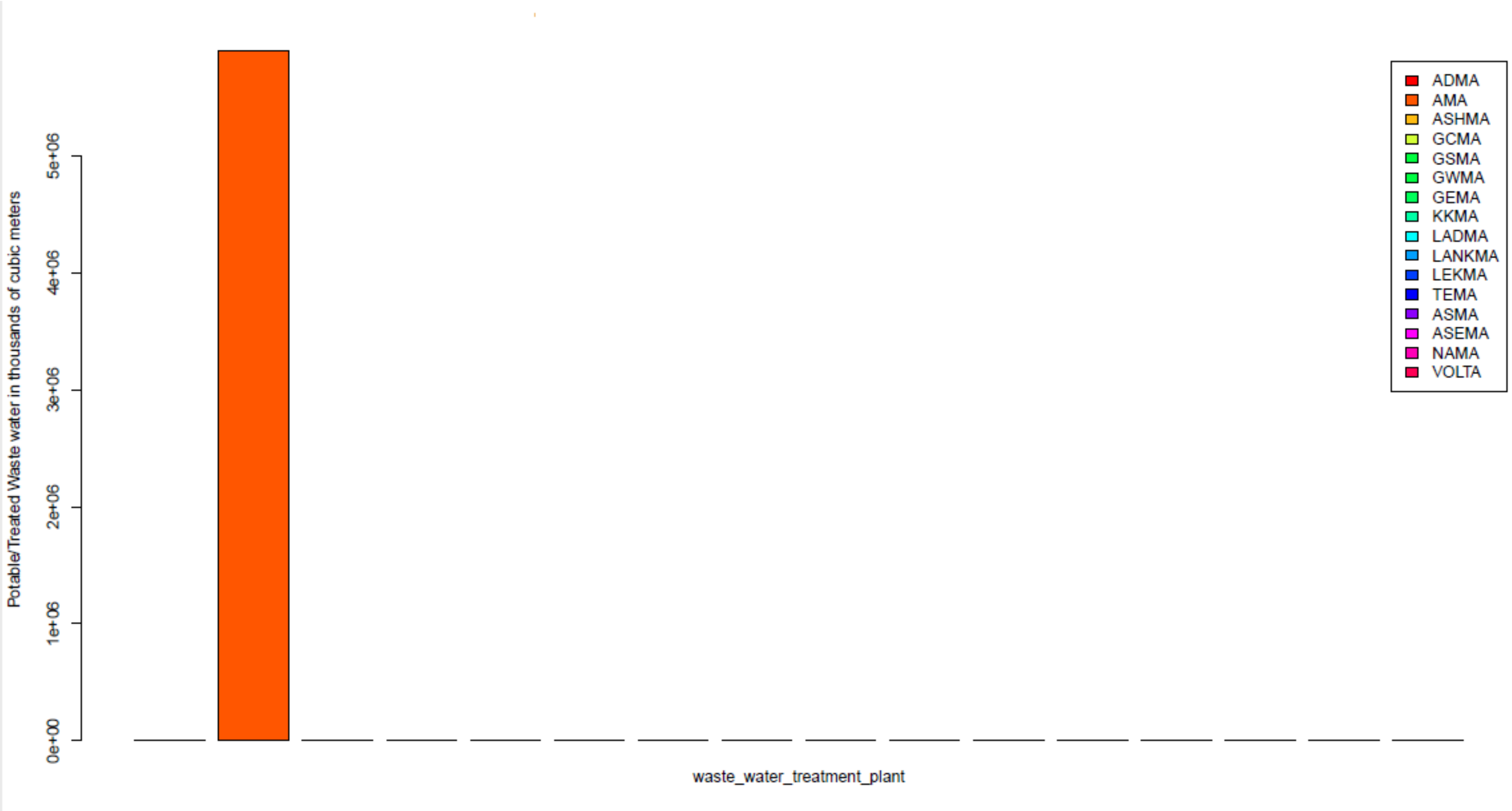


Figure 3.5 – Model generated graph for production rates per year for conventional waste water treatment plants in the **Decentralised Public Toilet Scenario** in 2030.

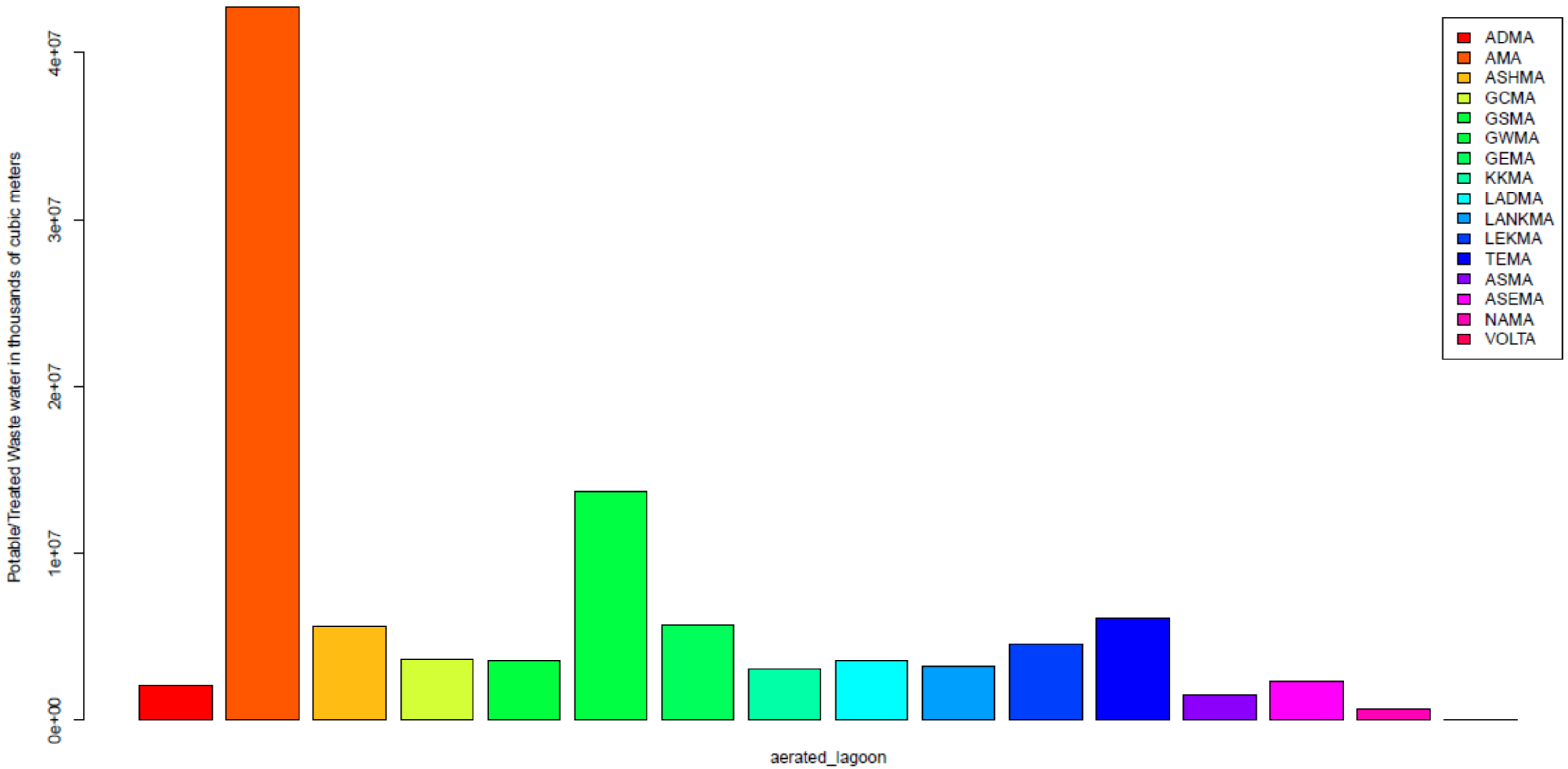


Figure 3.6 – Model generated graph for production rates per year for aerated lagoons in the **Decentralised Public Toilet Scenario** in 2030.

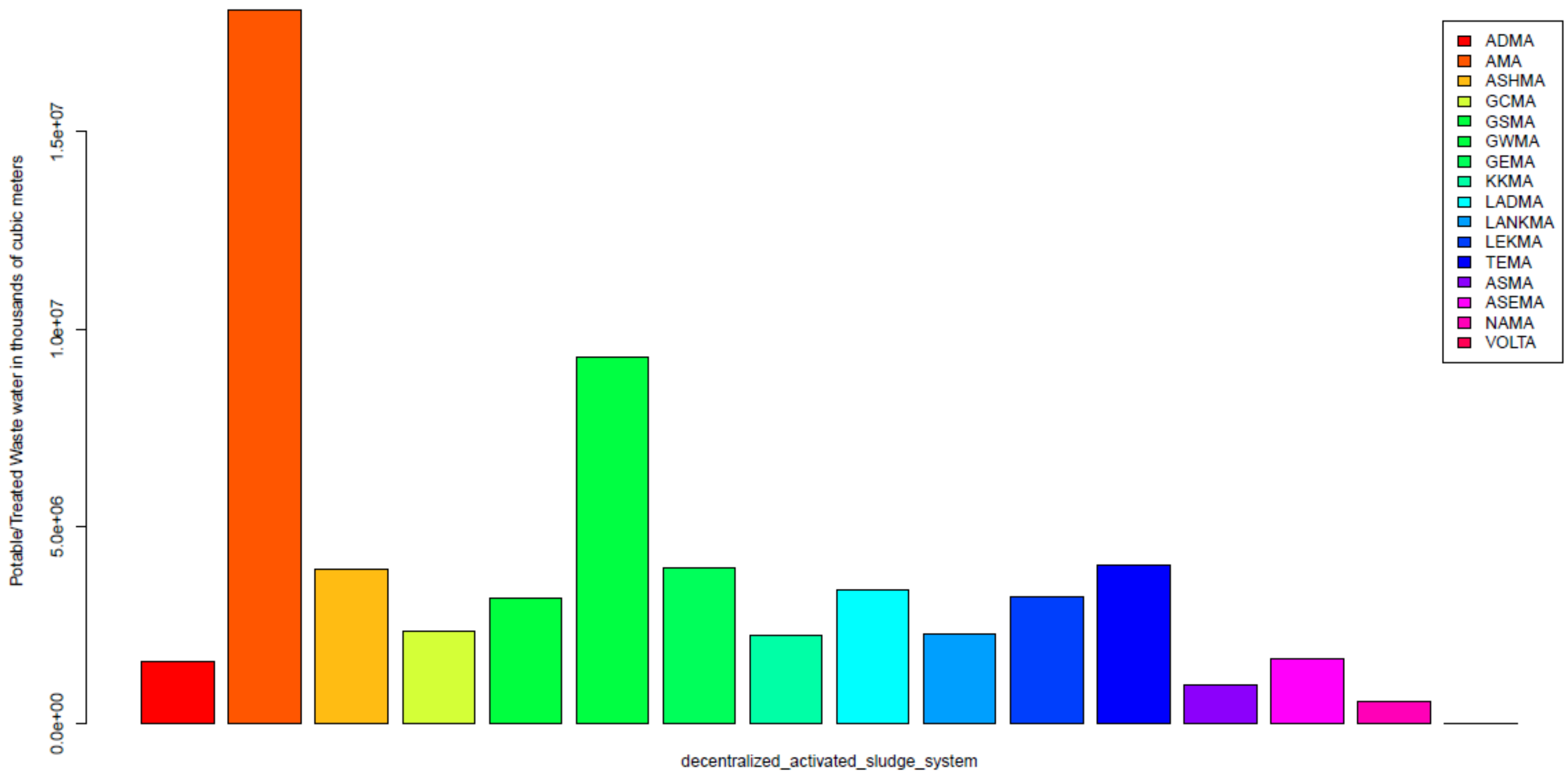


Figure 3.7 – Model generated graph for production rates per year for decentralised activated sludge systems in the **Decentralised Public Toilet Scenario** in 2030.

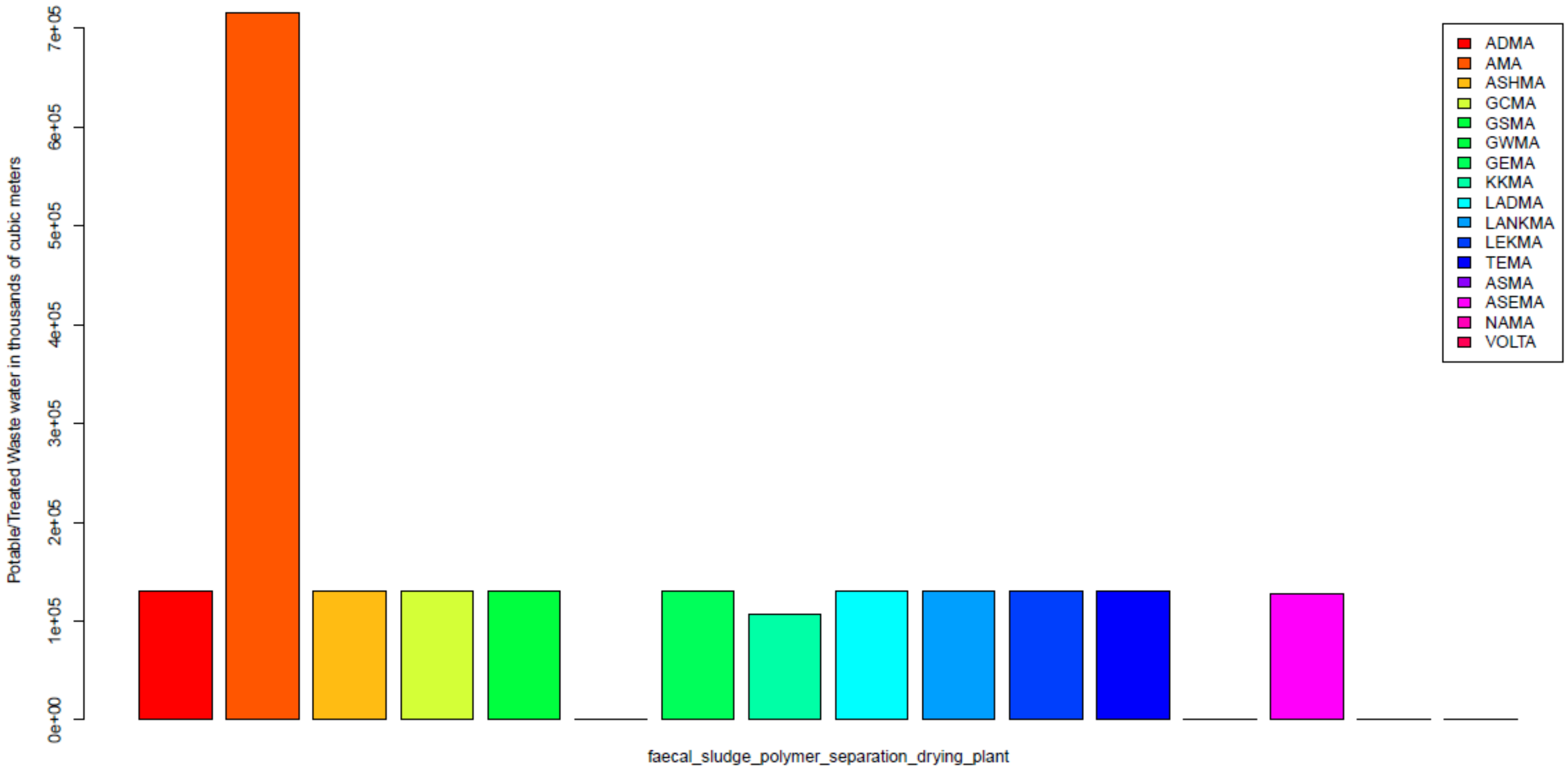


Figure 3.8 – Model generated graph for production rates per year for faecal sludge polymer separation drying plants in the **Decentralised Public Toilet Scenario** in 2030.

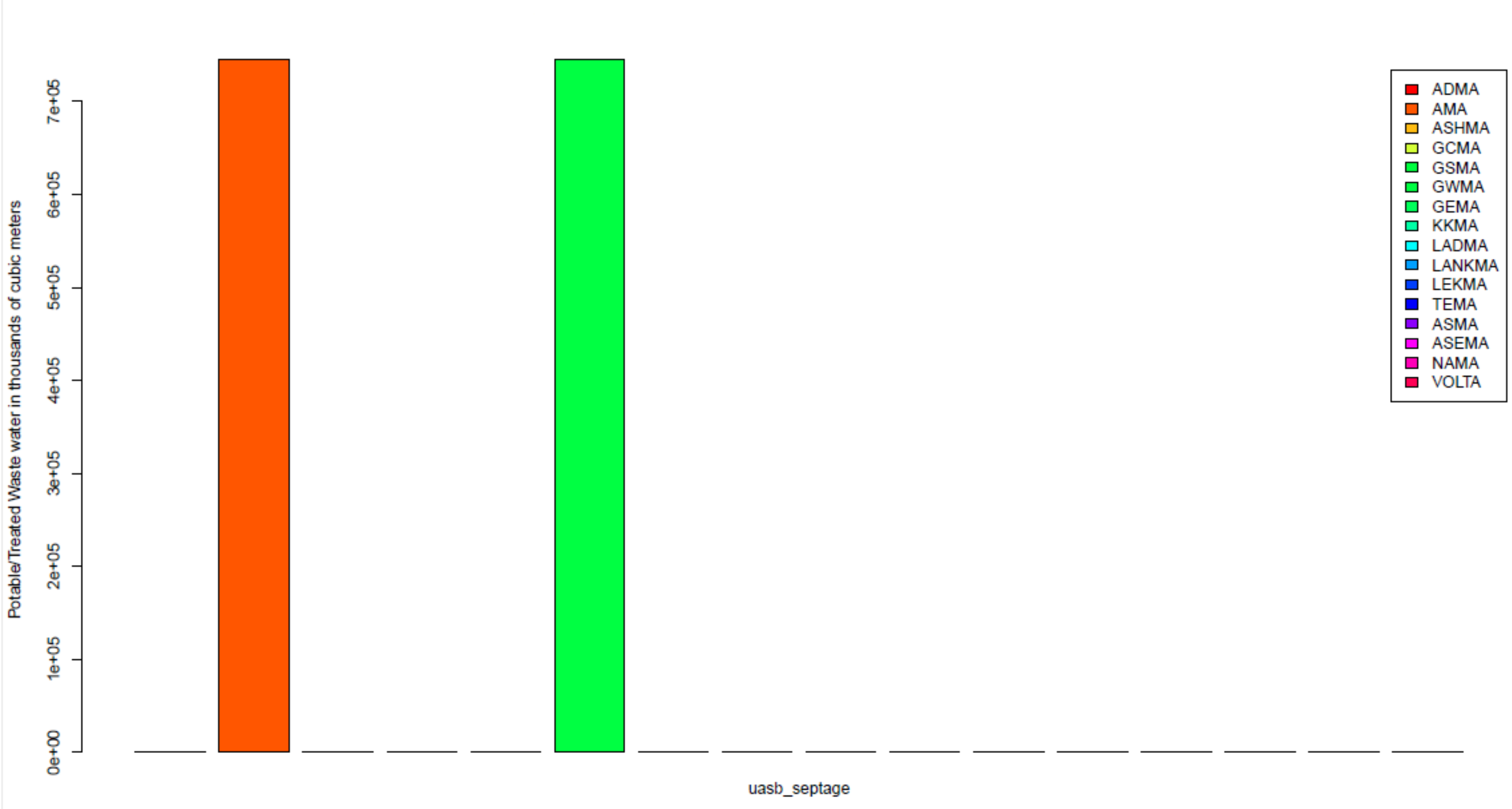


Figure 3.9 – Model generated graph for production rates per year for upflow anaerobic sludge blanket (UASB) reactor based Septage Systems in the **Decentralised Public Toilet Scenario** in 2030.

### 3.4.2 Results Labour and Electricity use

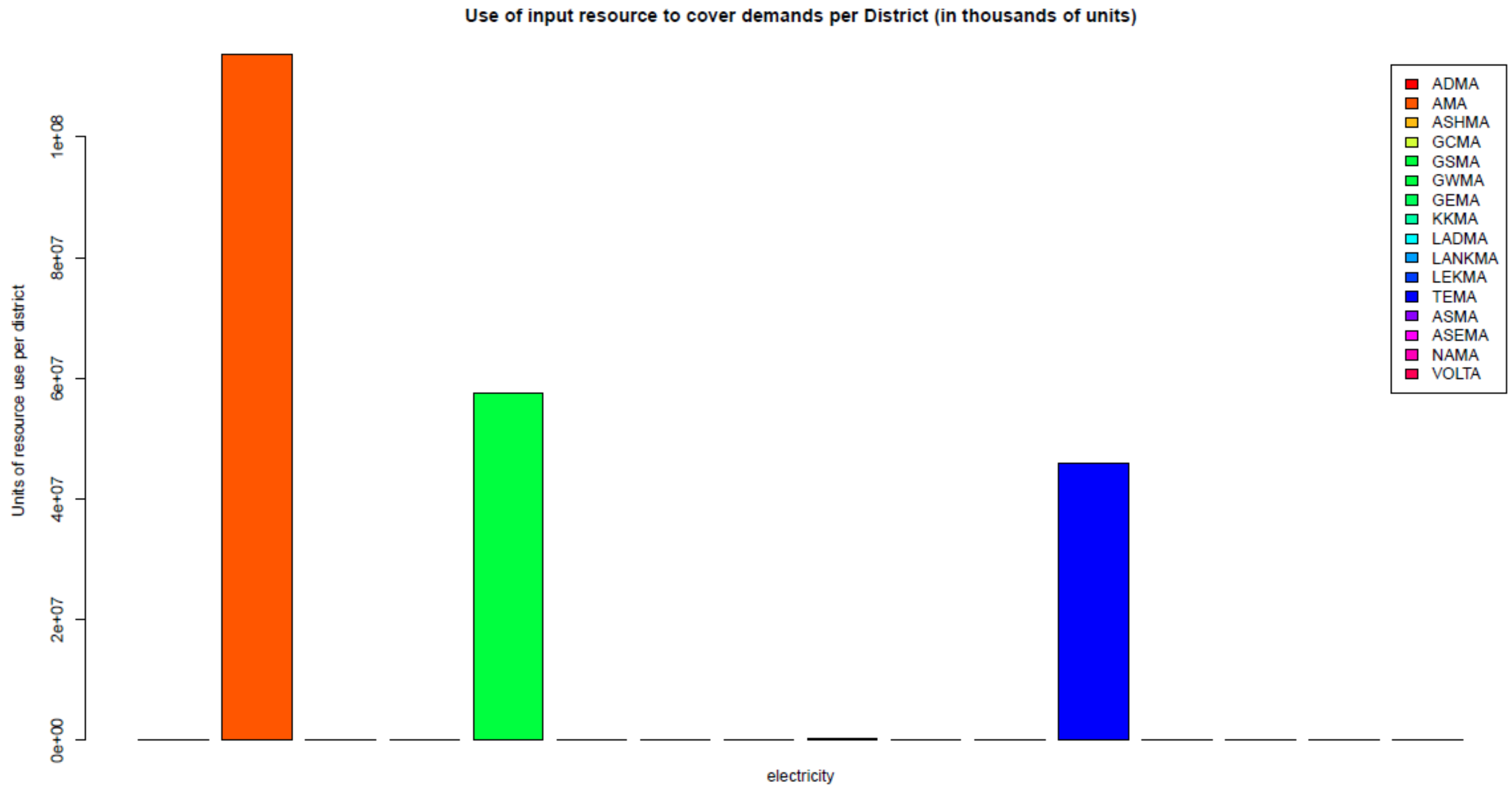


Figure 3.10 – Model generated graph of electricity use to cover waste-water treatment in MJ in the **Central Private Toilet Scenario** in 2030.

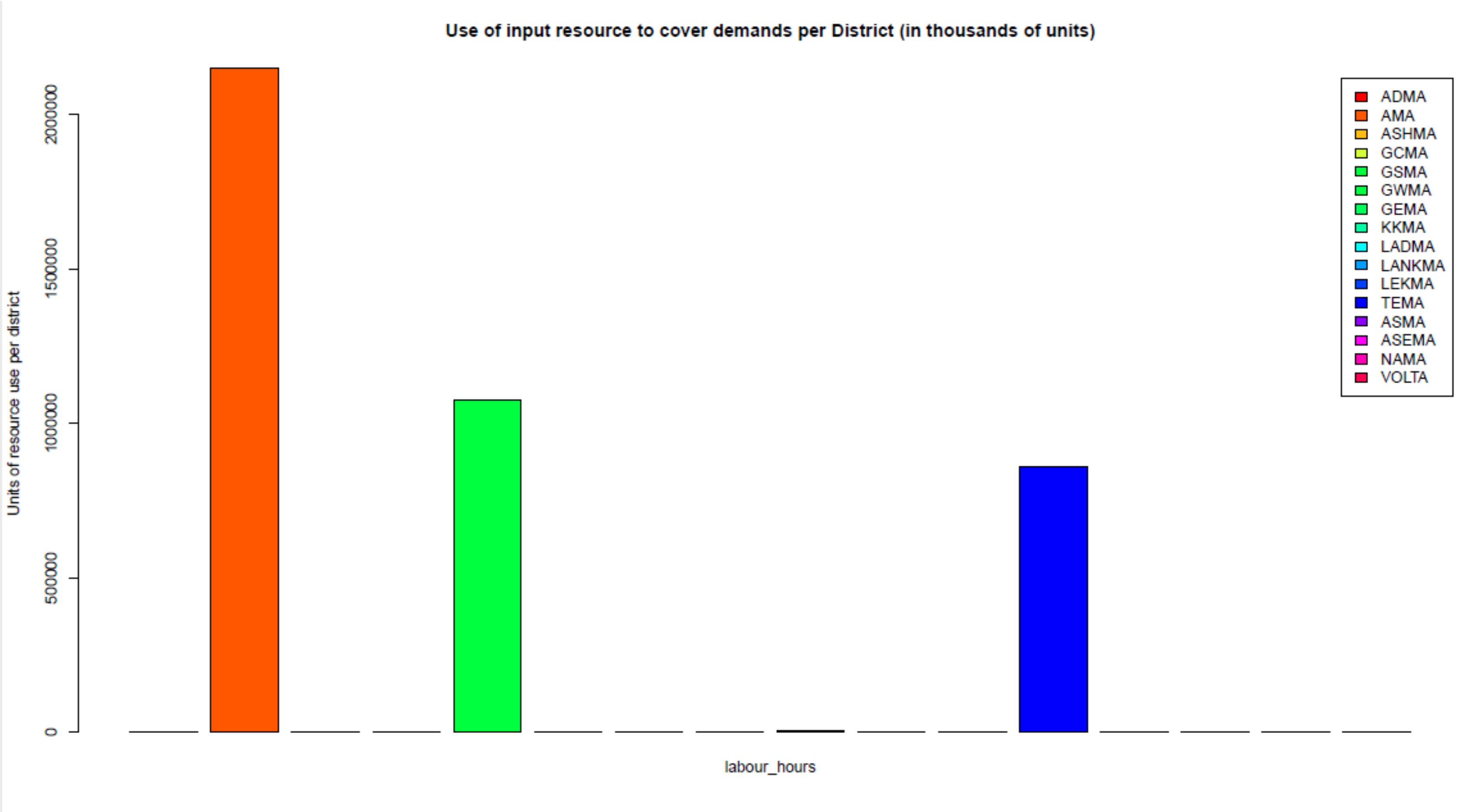


Figure 3.11 – Model generated graph of labour hour use to cover waste-water treatment in MJ in the **Central Private Toilet Scenario** in 2030.

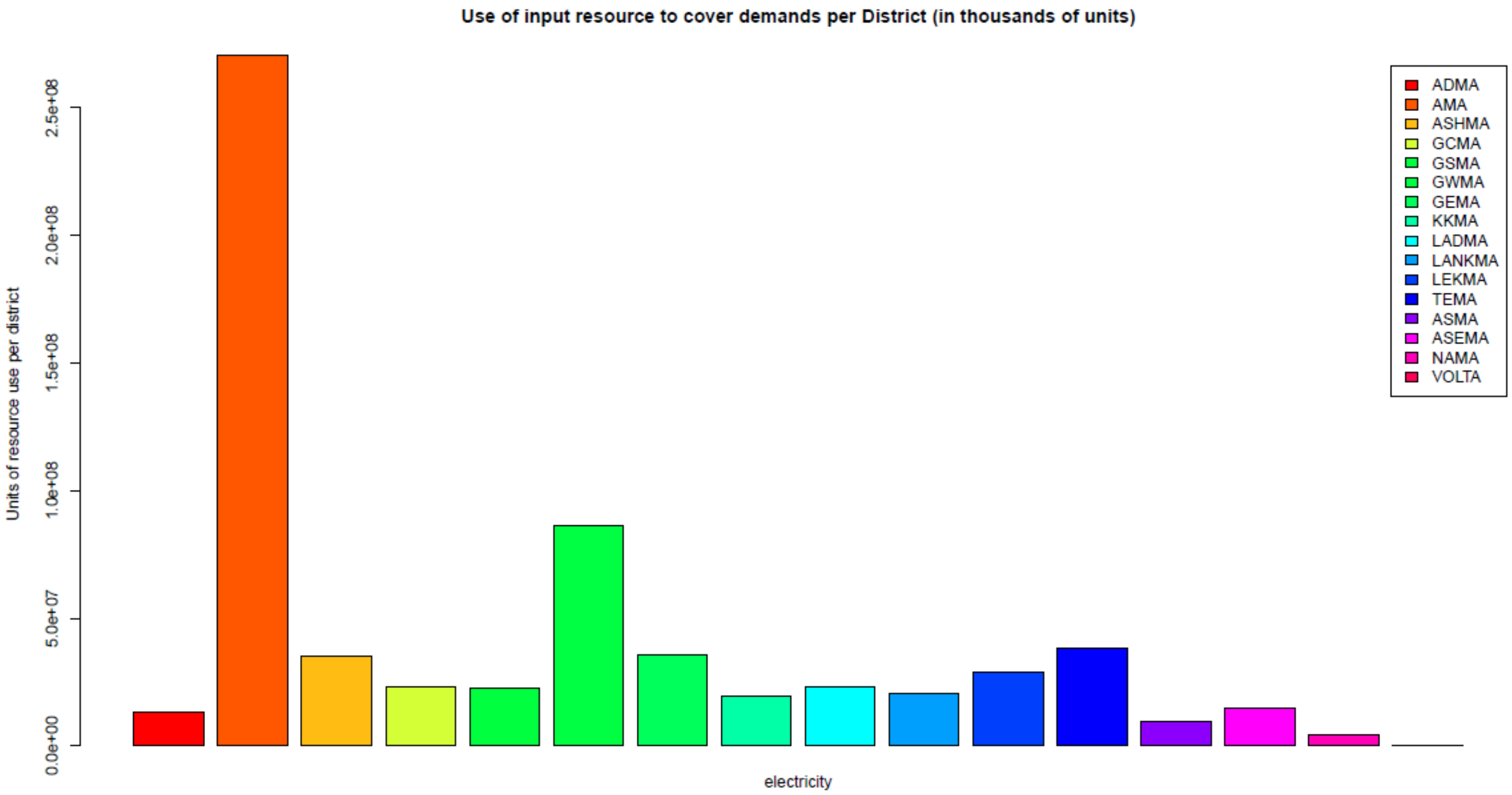


Figure 3.12 – Model generated graph of electricity use to cover waste-water treatment in MJ in the **Decentralised Public Toilet Scenario** in 2030.

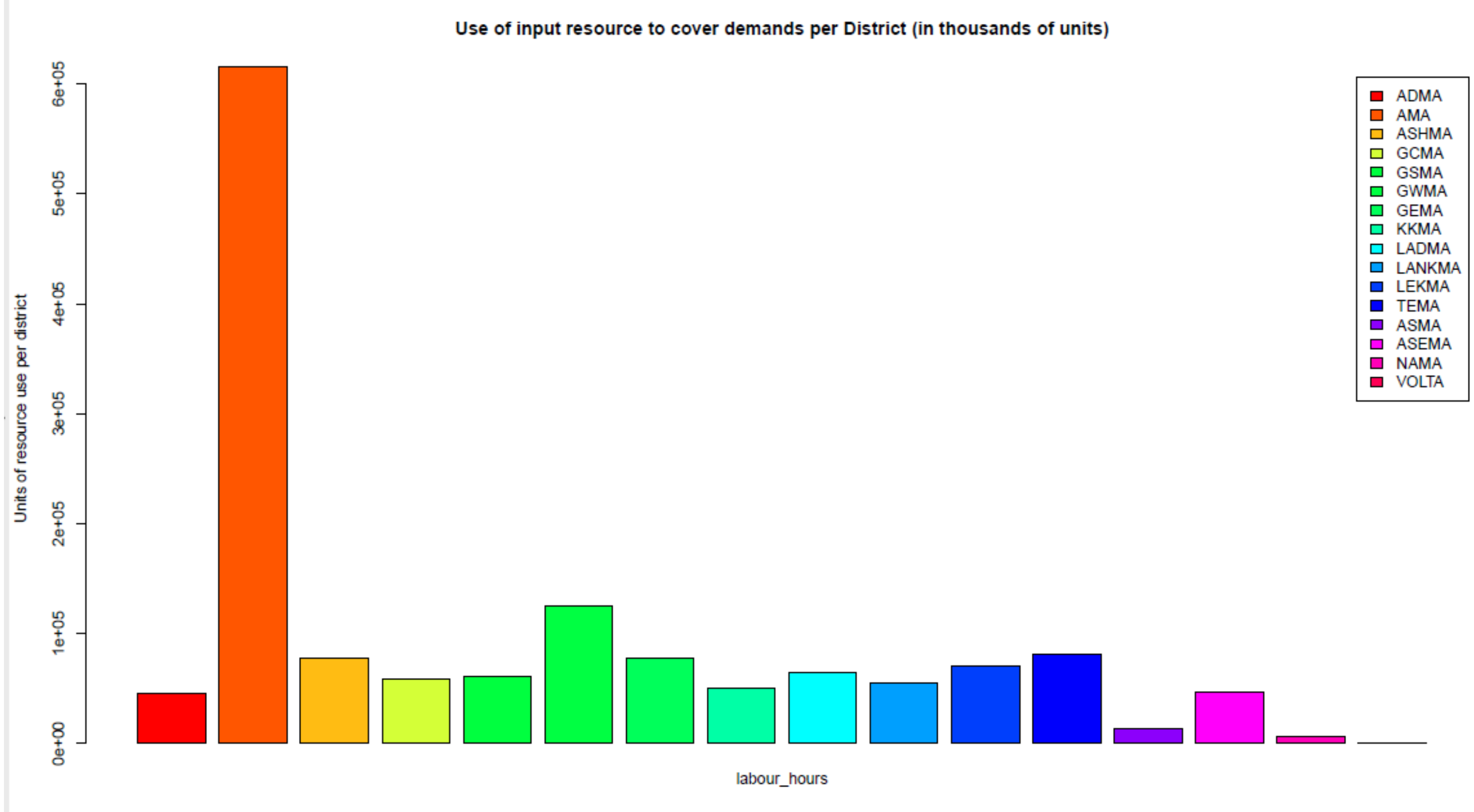


Figure 3.13 – Model generated graph of labour hour use to cover waste-water treatment in MJ in the **Decentralised Public Toilet Scenario** in 2030.

### 3.4.3 Results Pipeline Flows Comparison

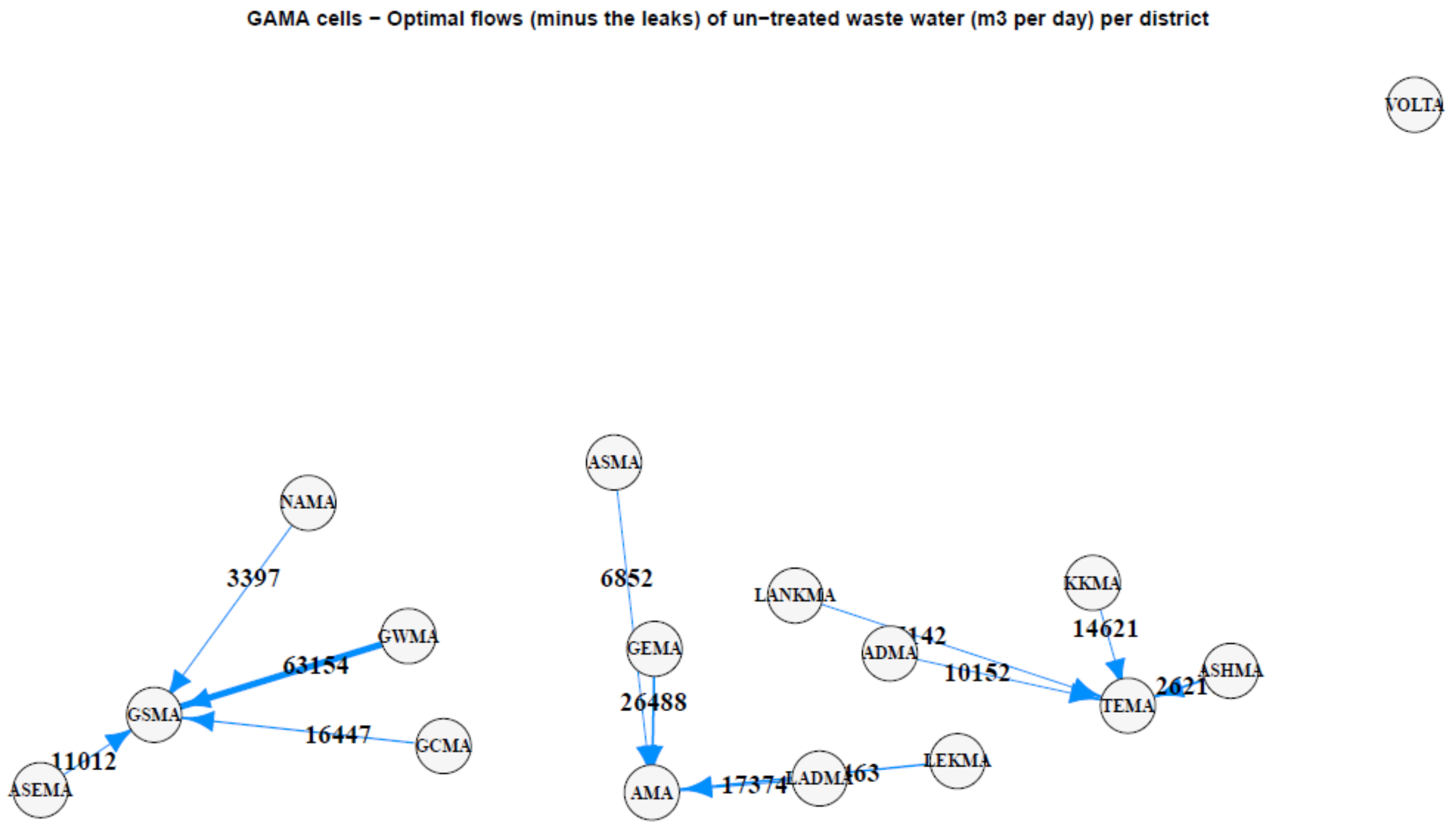


Figure 3.14 – Model generated graph of piped waste-water flows per day in **the Central Private Toilet scenario** in 2030.

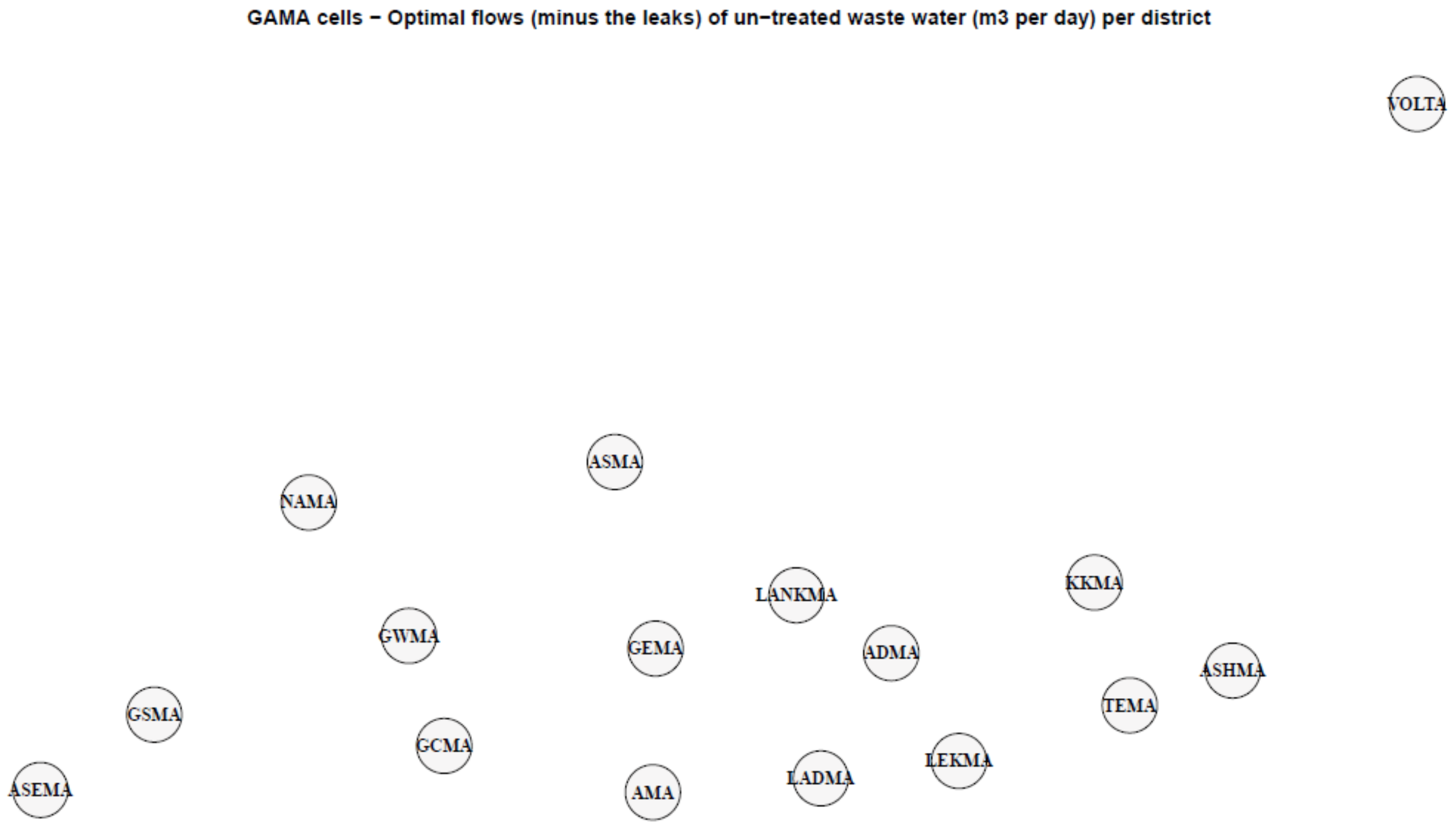


Figure 3.15 – Model generated graph of piped waste-water flows per day in **the Decentralised Public Toilet scenario** in 2030.

### 3.4.4 Results Biogas and charcoal briquettes Production Scenario

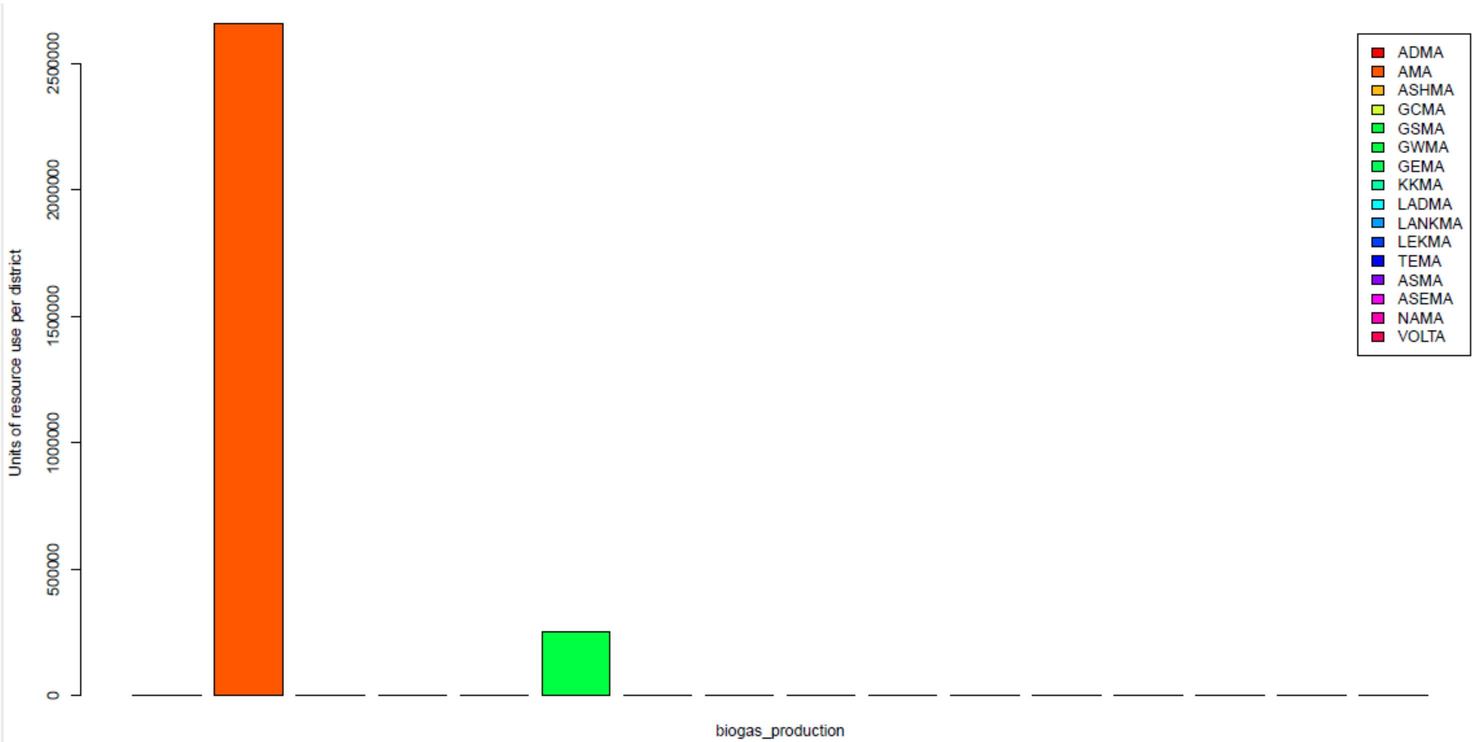

Figure 3.16 – Model generated graph of biogas production per day in **the Biogas and Charcoal scenario** in 2025

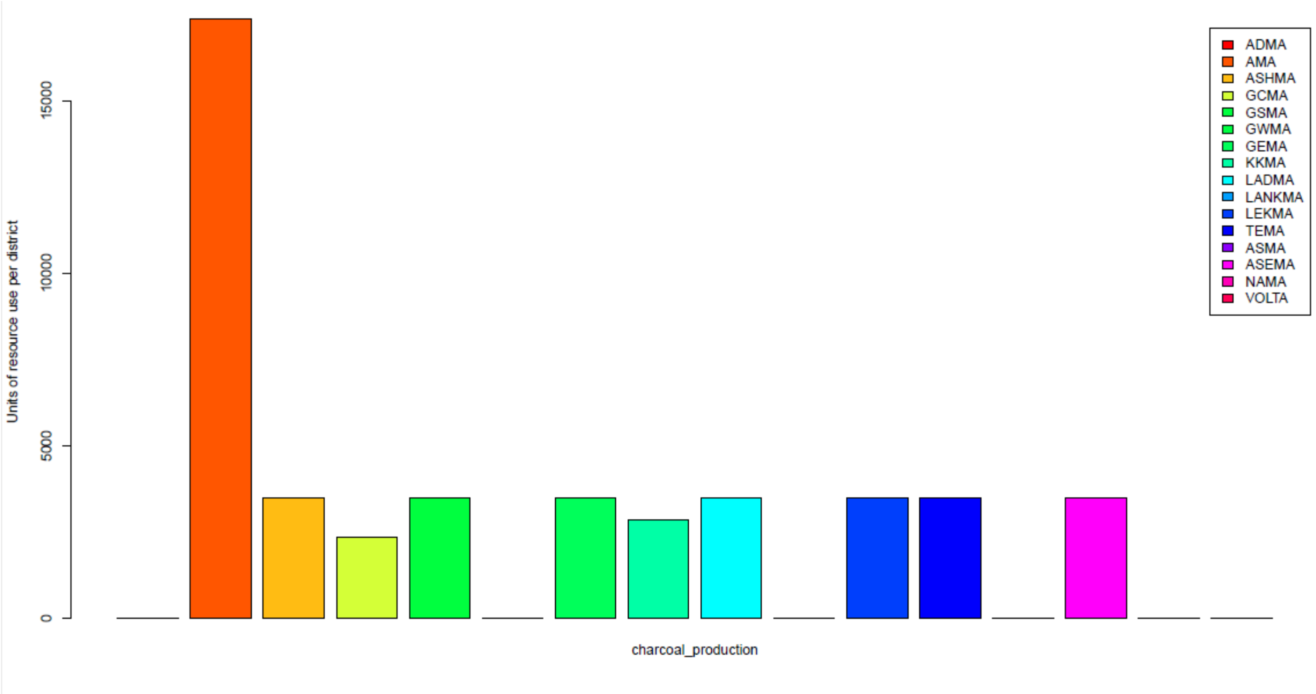


Figure 3.17 – Model generated graph of Charcoal production per day in **the Biogas and Charcoal scenario** in 2025

## 3.5 Discussion and Conclusions

The 3rd use case focuses on how the existing toilets and waste treatment systems can provide service in the sanitation sector, and more importantly what investment plans can be adopted to satisfy the Sustainable Development Goals of 100% access to improved sanitation. From the comparisons, the option of using decentralised treatment with public toilet systems is evaluated to be the best solution with respect to satisfying demand with minimal economic and environmental costs.

First of all, we take a look at the waste treatment infrastructure. The effects of toilets and waste-water treatment infrastructures can be evaluated by comparing a centralised treatment scenario with private toilets network and decentralised treatment with public toilets in 2030. In the centralized scenario the feacal sludge is largely absorbed in the large-scale waste-water treatment systems, whilst in the decentralized case faecal sludge is separately treated in dedicated systems associated with public toilets. The key difference with respect to technology choices are that instead of using central waste water treatment plant capacity of 904,400 $m^3$ per day, several effective decentralised technologies including aerated lagoon treatment plants, activated sludge, and faecal sludge polymer separation drying plants are adopted to satisfy the 100% waste-water treatment target. The accumulated capital expenditure for additional waste-water and faecal sludge treatment infrastructure using public toilets and decentralised systems is 0.41 billion USD over 20-year period from 2010 to 2030, which is significant lower than private toilets and central system with capital investment of 2.98 billion USD. However, the public toilet construction is found to be more expensive then private toilets, with a total expenditure of 0.30 billion USD over the 20 year period to build 4160 public toilets. In comparison the 265,000 private toilets built would cost only 0.17 billion USD.

The environmental side in terms of GHG emissions shows a substantial increase in faecal sludge related values. The estimated initial value is around 1780 tonnes in 2015, which grows in both scenarios to around 7500 tonnes in 2025. The calculations do not take into account what happens with the untreated faecal sludge that ends up in the environment such as the sea, however. A portion of this will likely be aerobically or anaerobically be converted by micro-organisms, and therefore also add up GHG emissions. Moreover, in relation to the volume of waste-water the emissions from waste-water treatment are a factor 10 higher. Based on total GHG emission values, the most important factor is reduction in waste-water treatment reductions.

Another observation from this case study is the utilization of faecal sludge only technology including UASB septage and decentralised faecal sludge polymer separation drying is less efficient compared with absorbing faecal sludge into waste-water central treatment. The influent faecal sludge is transited to be similar to waste-water so that it can flow around and then be treated in a normal waste-water treatment plant. Both the central and decentralised scenarios select some capacities of the faecal sludge polymer separation drying plants (11,987 and 11,401 $m^3$ per day respectively) as a small-scale economic affordable solution, with the UASB septage technology complementing treatment with an ongoing application of 4,080 $m^3$ per day in the decentralized system. Instead, the central waste water treatment plant has an accumulative capacity of 904,400 $m^3$ per day in the private central treatment scenario, while for the public decentralised scenario, a much smaller capacity of 16,150 $m^3$ per day is suggested for a central treatment plant, plus 659,175 $m^3$ per day of distributed aerated lagoon treatment plants.

For toilets coverage, the results suggest a profile of additional public/private toilet infrastructure investment under different priorities between public and private facilities. An estimated total of 703,142 private toilets need to be constructed over 2010-2030 to cover the 100% sanitation needs. While 9,779 public toilets of an average 320-use per day design capacity can provide the same functionality meeting SDG goals. The capital expenditure of the former central private toilet scenario adds up to 30.5 million USD, and the latter decentralised public toilet scenario until 2030 is 17.1 million USD. The private toilets construction plan almost doubles the capital costs of utilizing public toilets in a large scale. Moreover, considering the charged fees to use public toilets, 270 million USD can be collected as revenues over the 20-year period. If the fee to use public toilets per time is double of the operational costs of toilets including electricity, water and labor use, a net profit of 105 million USD can be earned from the public toilets service sector. The jobs associated with faecal sludge treatment and collection from toilets were also evaluated. Since there is limited infrastructure in place at present the values grow substantially as the infrastructure expands. At the initial level the values were estimated around 161 jobs for cesspit tanker transport to the shore. These values grow to a number of 1753 jobs in the public toilet with decentralised treatment, and 625 jobs in the private toilet with centralised treatment scenario. In both cases there is ample opportunity for job creation and growth. These values do not include the additional jobs that would be created for the operation of the toilets themselves.

The additional benefits of biogas production and charcoal briquettes were quantified in the separate scenario. It was found that by assuming methane produced in central waste water treatment as well as UASB and anaerobic digestion, nearly 3 million $m^3$ of biogas can be produced every year. Similarly, the solid output of the polymer separation and drying plants for faecal sludge treatment were assumed to be turned into charcoal briquettes, as already currently done within the AMA district at the Jamestown drying plant. The total output of this when scaled to GAMA can grow substantially towards a level of 47,000 tonnes per year by 2025. The value of using the methane instead of letting it be released in the atmosphere is substantial at close to 0.6 million USD per year. The best use for large-scale treatment is plausibly direct generation of electricity at the treatment plant site for usage, and at small-scale for sales into gas tanks after treatment. The value of charcoal briquettes is much higher given the large quantities, and represents nearly 5 million USD by 2025, sufficient to make a real impact on operational costs of the WASH treatment system in Ghana. In the calculations the full energy value of the biogas was taken in MJ, and it was assumed to be half the value of electricity, resulting in a price of 0.2 USD per $m^3$ of biogas. In case of briquettes an existing market within Accra for charcoal exists from which a price of 0.4 GHS per kilogram was taken.

Last, it is implicated that the electricity requirements and cost in decentralised public toilet system is almost tripled versus private toilets of a central treatment system, but it bears much lower labour needs (only one third compared with the central system). The wide distribution of public toilets can create more job opportunities (a total of 2010 job positions) for low-level of techniques requirement, which may pose positive benefits to the society. Overall the trade-off of high electricity demand versus labour requirements does not prevent the decentralised public system to be a preferred solution.

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GAMA WASH use cases

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