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An integrated, model-based approach to evaluate WASH sector investment options

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Water SDGs and Future Water Management Symposium
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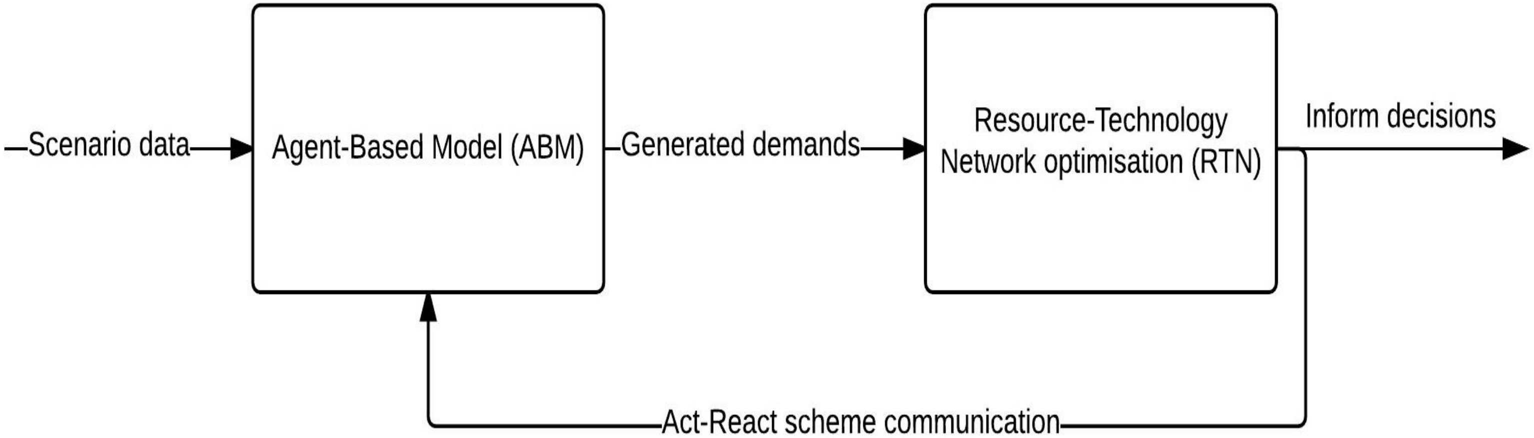
Motivation

- Water at the core of sustainable development
- Reaching SDGs in Sub-Saharan Africa
- Non-commercial & open-source tool
- Support DFID

resilience.io

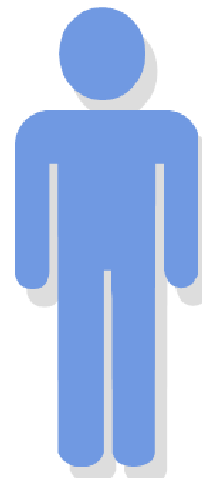


Software components

- YAML, for easy human-readable data input
- JAVA, for programming the ABM and RTN modules
- GLPK, as the MILP optimization solver
- R, for post-processing and visualizations

ABM: Agent characteristics

- gender
- age
- work force status
- income status
- home/work location



agent

Calculation method

- Initialize population – agents with socio-economic characteristics
- Generate a synthetic group (~0.01%)
- Estimate for each agent toilet use throughout the day, based on probability-of-activity model
- Multiply toilet use times by amount of urine and excreta generated per use to yield total amount of accumulation at a toilet site, and total human sewage generated per day

How RTN works

- Production rates – satisfy demands
- Technology balance – investments
- Amount of raw / imported resources?
- Resource surplus; better to flow or build infrastructure?

→ Minimize cost + CO_2 emissions

Calculation method

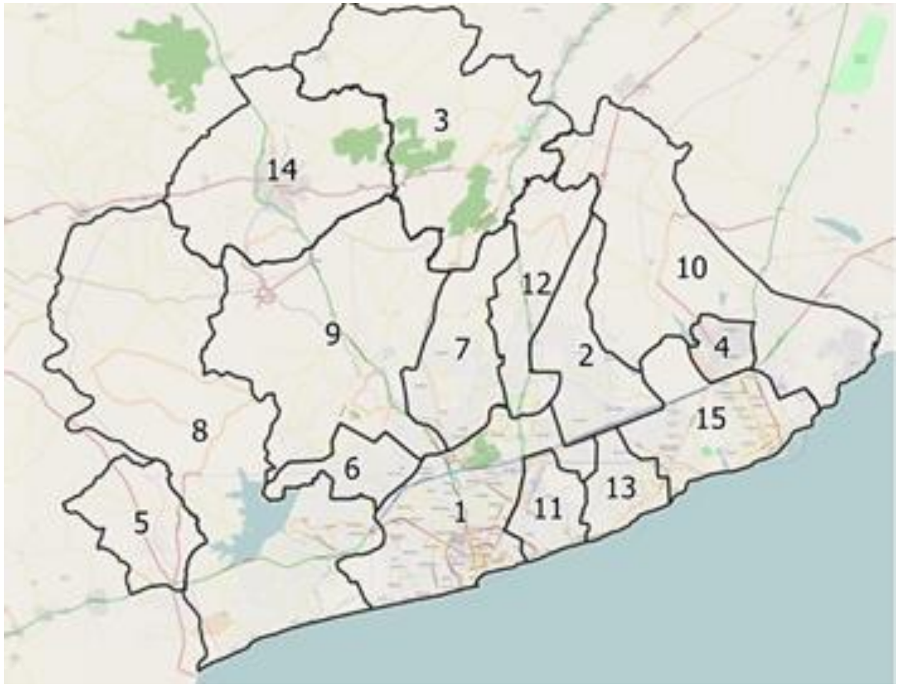
- Initialize model with demands, initial infrastructure etc.
- Set desired objectives for calculation
- How to meet these targets based on a large number of settings?
- Fine constraints to tailor the case to specific realistic policies/needs

Flexible functionality

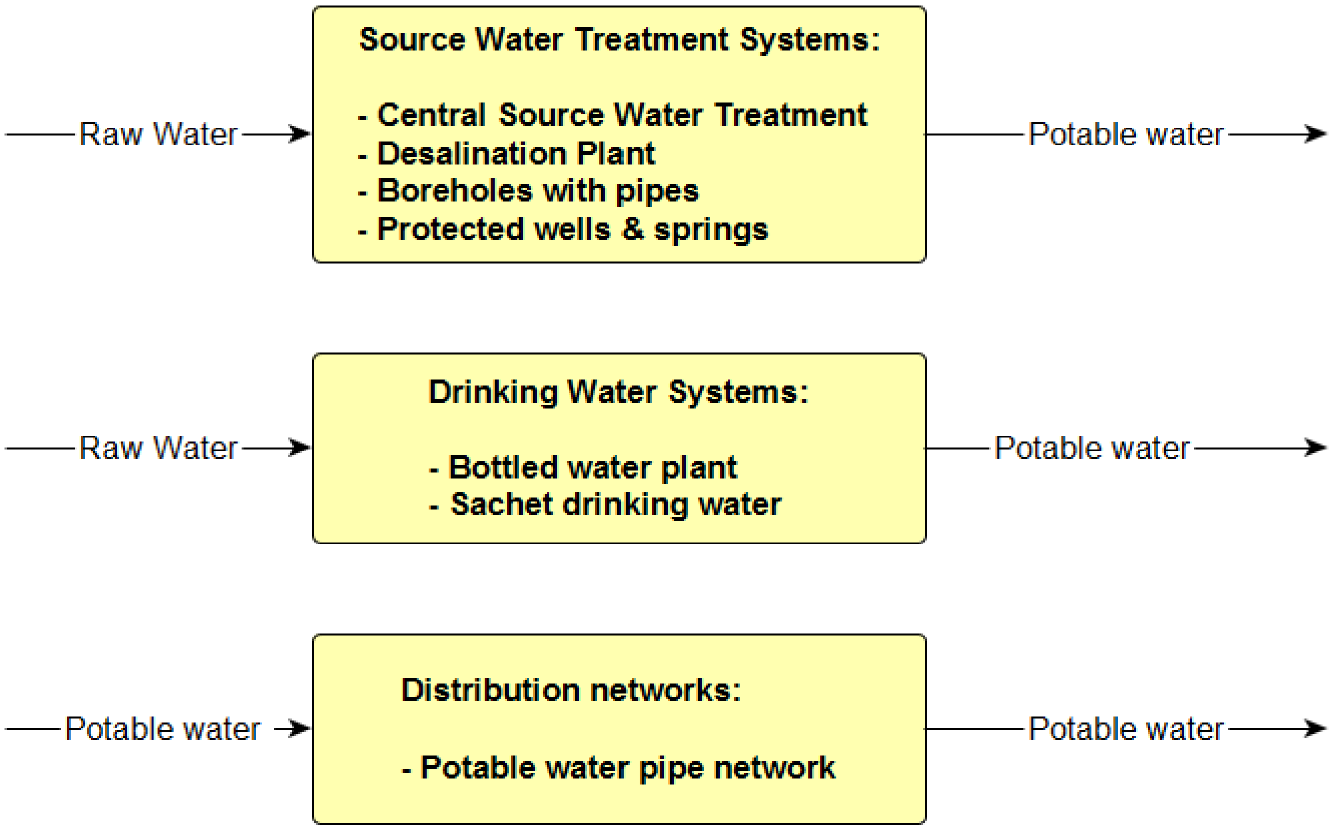
- upper bound network flows (or even make certain only resources able to flow)
- pipe expansion capability
- define which resources can be imported
- geo-localization affects calculations
- define different weights on the optimized metrics
- define percentages of met demands per year, different for each resource in demand
- pre-allocate infrastructure
- specify leaks on flows
- specify minimum production load on technological infrastructure
- Upper bound the capital expenditure costs

Application: WASH in GAMA

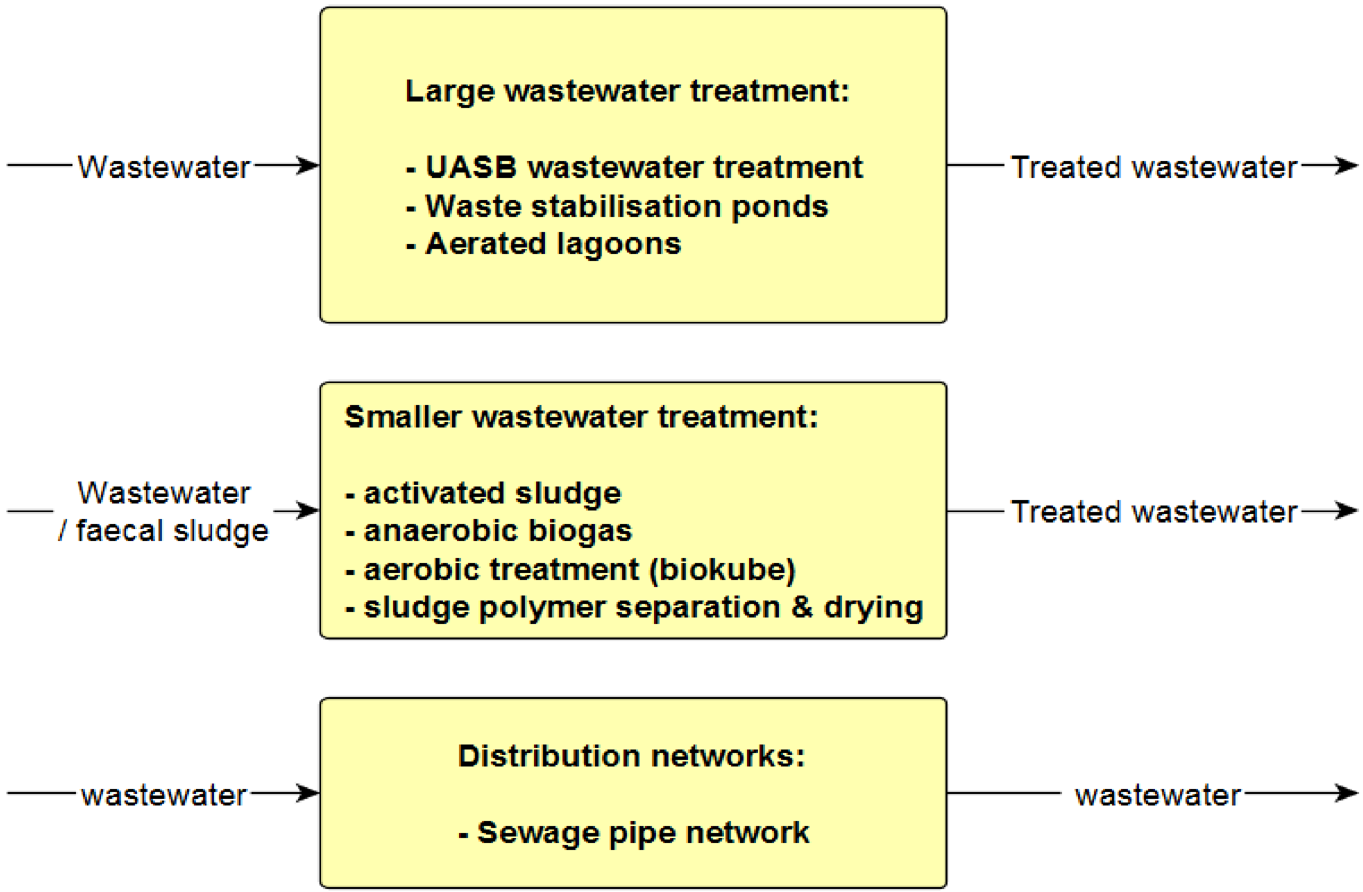
- Source water treatment
- Potable water distribution
- Water demands and usage
- Waste water treatment
- Associated costs/investments in different scenarios



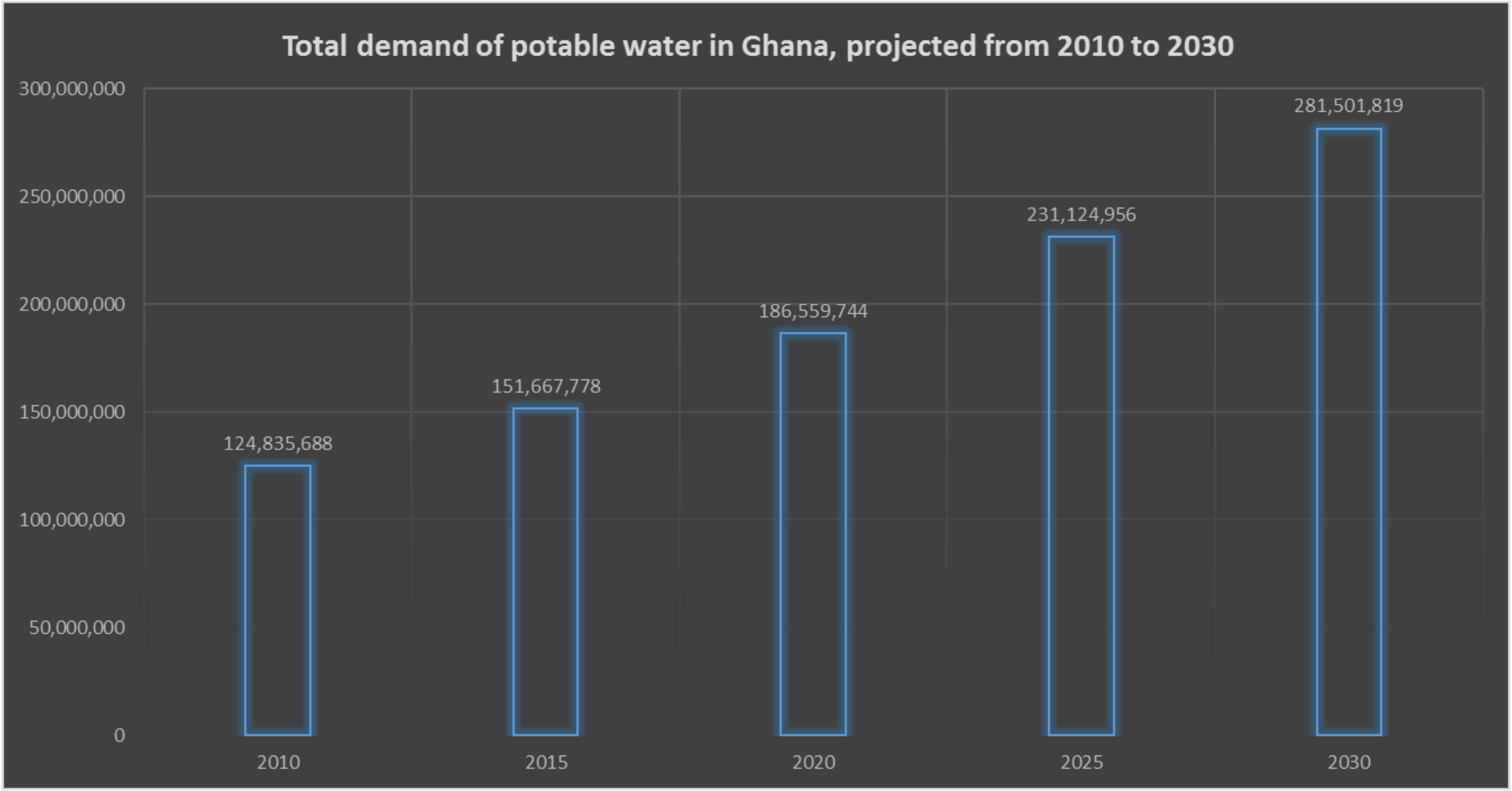
Technology datasets - potable water



Technology datasets - wastewater



Estimated projection of demands (m^3) in clean water



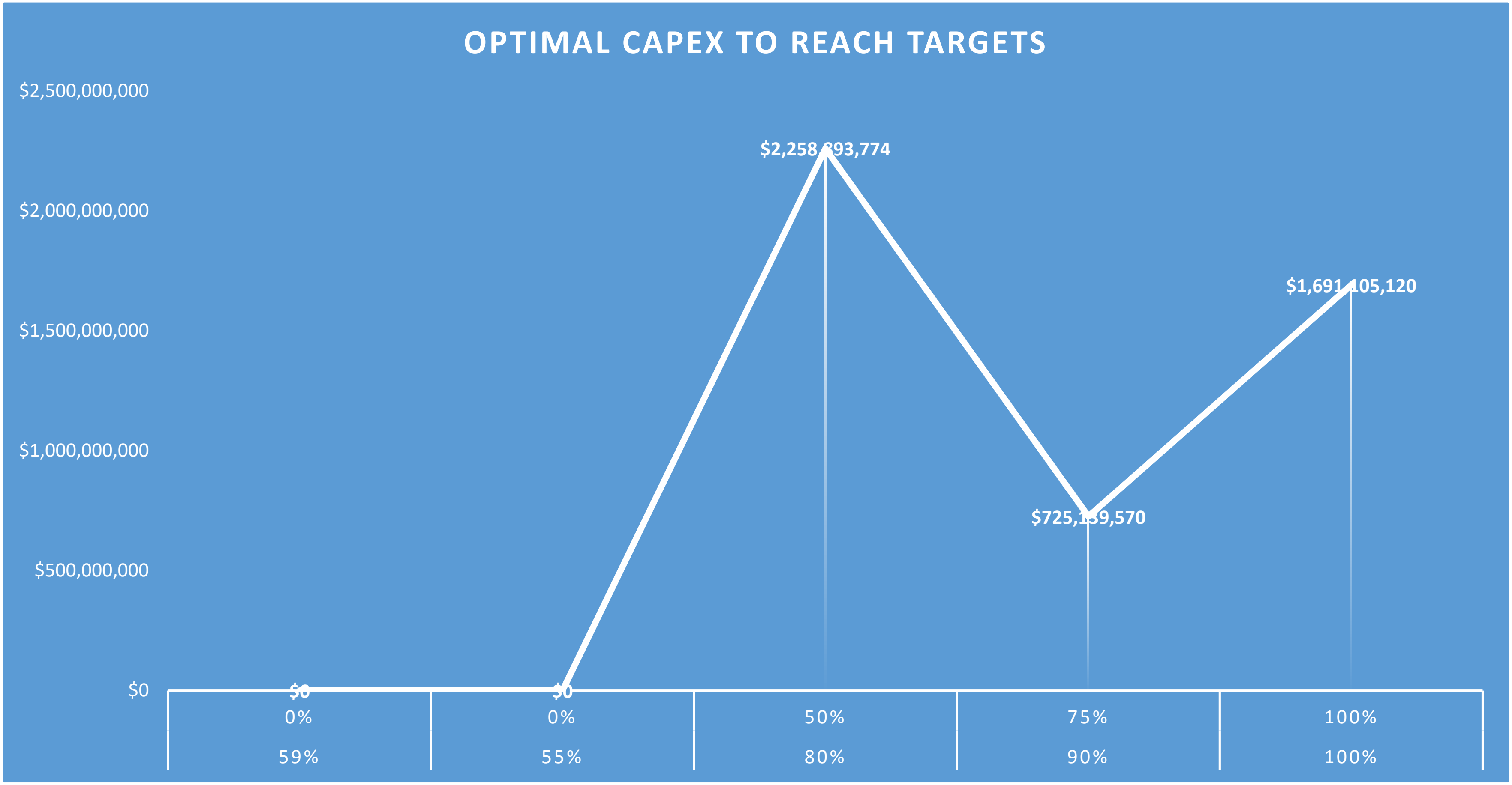
Results-metrics

scenario1	YEARS	Potable m^3 total demand	CAPEX PREALLOCATED	OPTIMAL CAPEX	OPTIMAL OPEX	OPTIMAL CO_2 (kg)	CO_2 (g/m^3)	POTABLE	WASTE	LEAKS
	2010	124,835,688	$14,870,375,398	$0	$19,110,745	836,522.01	3.72	27%	0%	27%
	2015	151,667,778	$14,870,375,398	$0	$19,722,456	884,349.04	3.24	24%	0%	27%
	2020	186,559,744	$14,870,375,398	$0	$19,025,893	870,810.99	2.59	20%	0%	27%
	2025	231,124,956	$14,870,375,398	$0	$21,098,393	977,075.21	2.35	17%	0%	27%
	2030	281,501,819	$14,870,375,398	$0	$20,109,560	959,621.16	1.89	15%	0%	27%
scenario2										
	2010	124,835,688	$14,870,375,398	$0	$19,110,745	836,522.01	3.72	27%	0%	27%
	2015	151,667,778	$16,097,080,996	$0	$39,636,526	4,638,937.10	16.99	26%	0%	27%
	2020	186,559,744	$17,394,890,493	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE
	2025	231,124,956	$17,394,890,493	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE
	2030	281,501,819	$17,394,890,493	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE	INFEASIBLE
scenario5										
	2010	124,835,688	$14,870,375,398	$0	$48,716,293	1,493,915.51	6.65	59%	0%	27%
	2015	151,667,778	$16,097,080,996	$0	$76,936,268	5,240,937.57	19.20	55%	0%	27%
	2020	186,559,744	$17,394,522,093	$2,258,893,774	$160,012,542	50,187,077.68	149.45	80%	50%	24%
	2025	231,124,956	$17,394,149,893	$725,139,570	$162,946,515	90,735,765.59	218.10	90%	75%	20%
	2030	281,501,819	$17,393,777,743	$1,691,105,120	$223,927,588	145,745,404.55	287.63	100%	100%	20%

Optimal inputs of electricity and labour

scenario1	YEARS	electricity(MJ)	labour hours	electricity (kW)	kW/m^3	FTEs (year)
	2010	34,057,459.81	1,233,155.38	*9,460,405.51*	*0.04*	*593*
	2015	36,311,048.73	1,210,954.06	*10,086,402.43*	*0.04*	*582*
	2020	37,494,494.26	1,051,558.59	*10,415,137.30*	*0.03*	*506*
	2025	39,435,232.27	1,193,971.69	*10,954,231.20*	*0.03*	*574*
	2030	41,627,900.65	980,209.57	*11,563,305.74*	*0.02*	*471*
scenario2						
	2010	34,057,459.81	1,233,155.38	*9,460,405.51*	*0.04*	*593*
	2015	292,506,850.33	2,018,503.40	*81,251,902.94*	*0.30*	*970*
	2020	INFEASIBLE	INFEASIBLE	*INFEASIBLE*	*INFEASIBLE*	*INFEASIBLE*
	2025	INFEASIBLE	INFEASIBLE	*INFEASIBLE*	*INFEASIBLE*	*INFEASIBLE*
	2030	INFEASIBLE	INFEASIBLE	*INFEASIBLE*	*INFEASIBLE*	*INFEASIBLE*
scenario5						
	2010	54,537,556.02	7,791,664.82	*15,149,321.13*	*0.07*	*3,746*
	2015	428,311,009.96	9,004,383.88	*118,975,280.64*	*0.44*	*4,329*
	2020	709,591,516.87	14,191,913.54	*197,108,754.84*	*0.59*	*6,823*
	2025	934,579,308.13	11,047,920.40	*259,605,363.58*	*0.62*	*5,312*
	2030	1,333,848,840.16	11,445,309.25	*370,513,567.01*	*0.73*	*5,503*

SDGs: Projection of CAPEX in 2010-2015-2020-2025-2030



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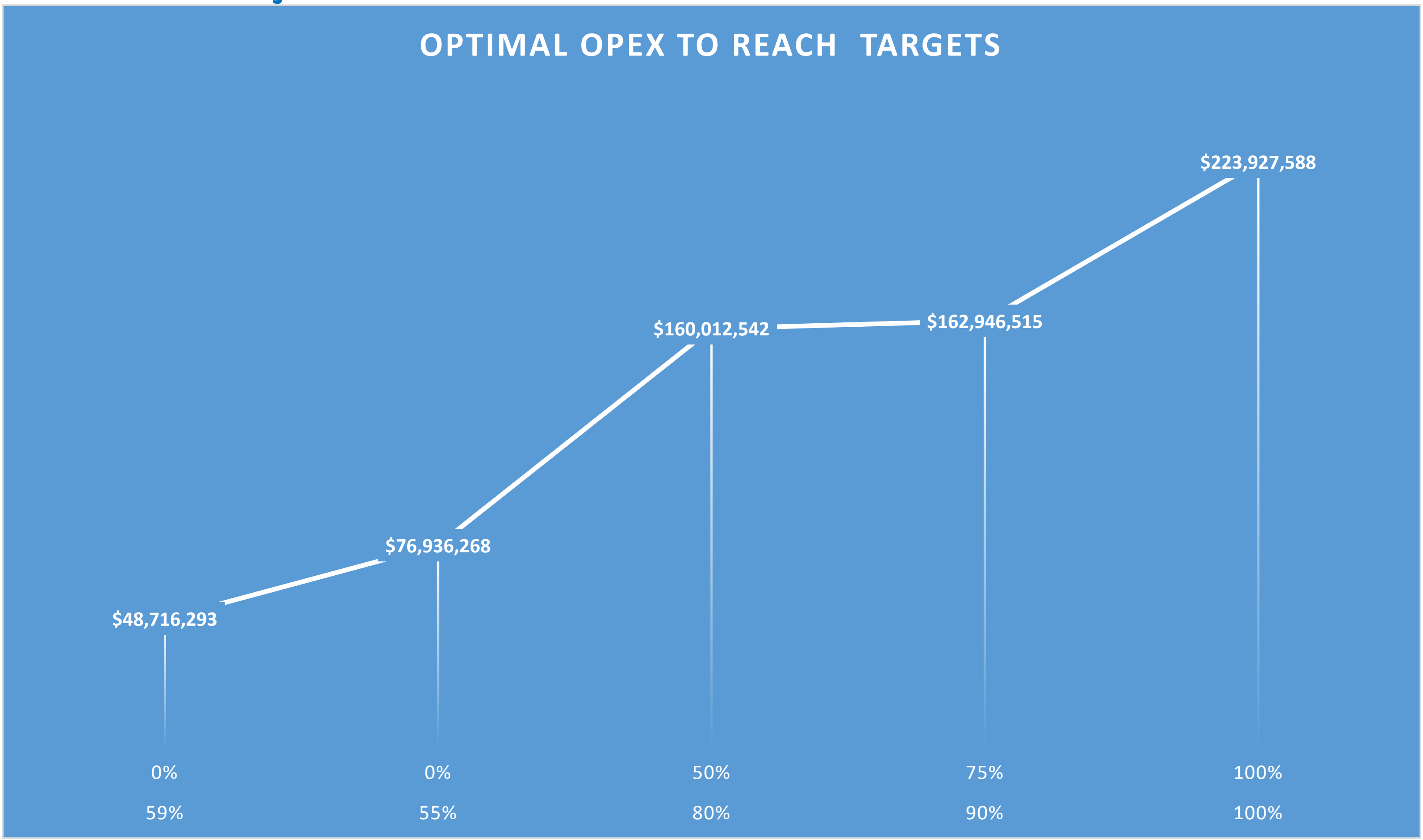
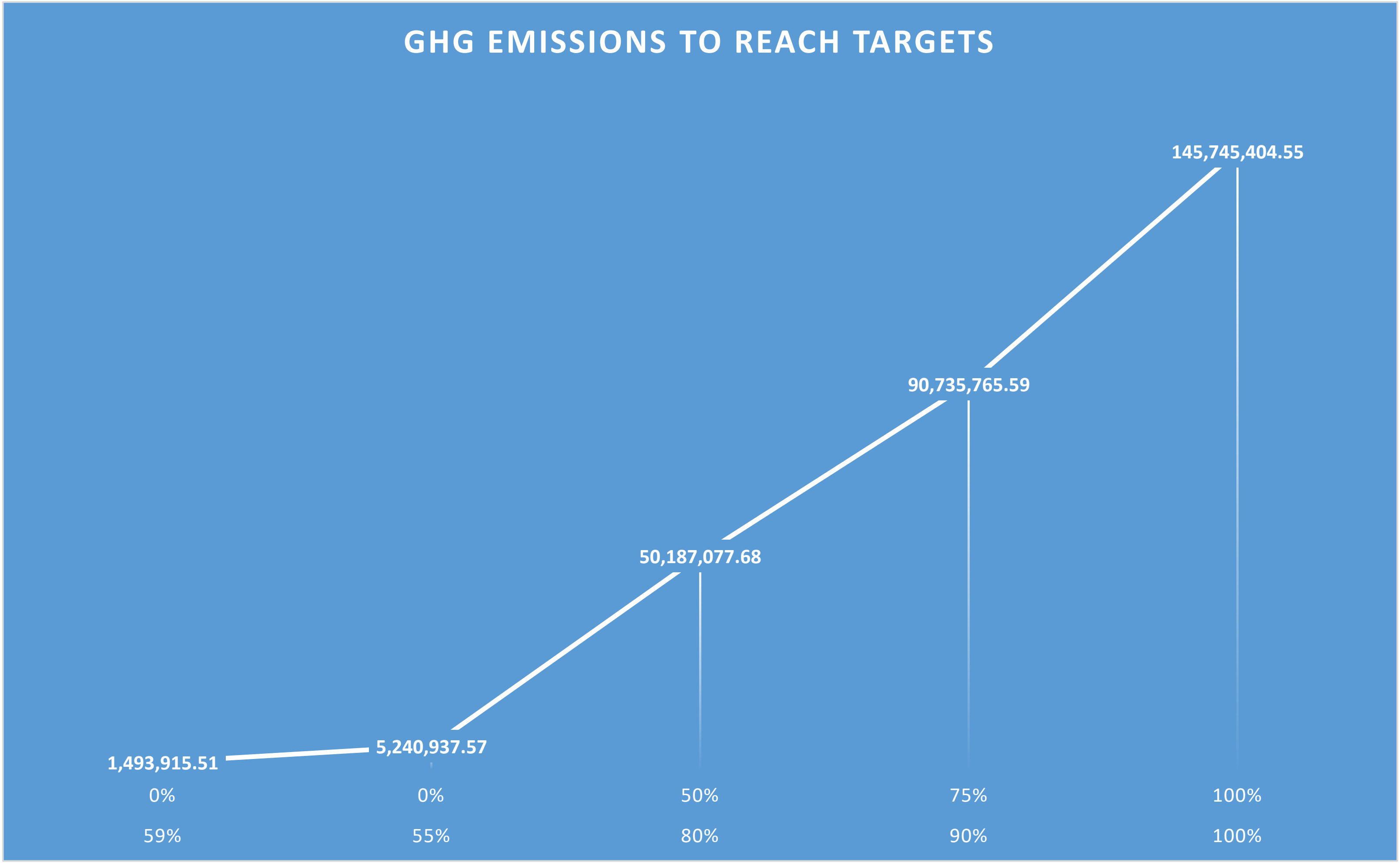
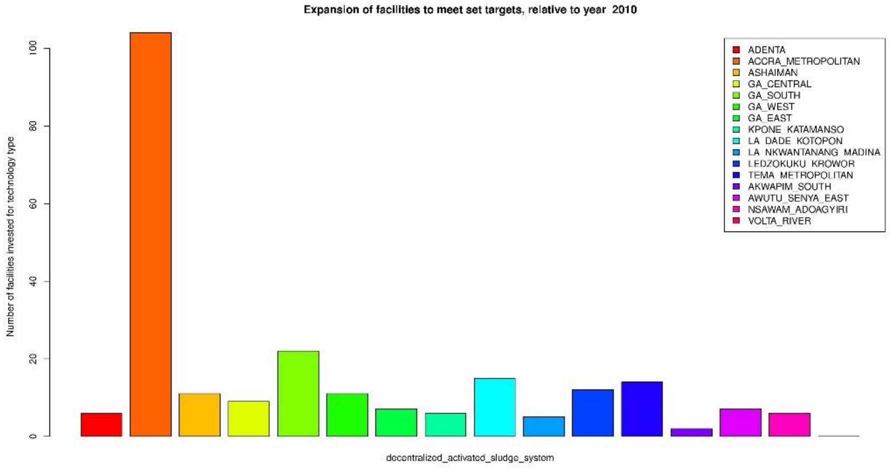
SDGs: Projection of OPEX in 2010-2015-2020-2025-2030

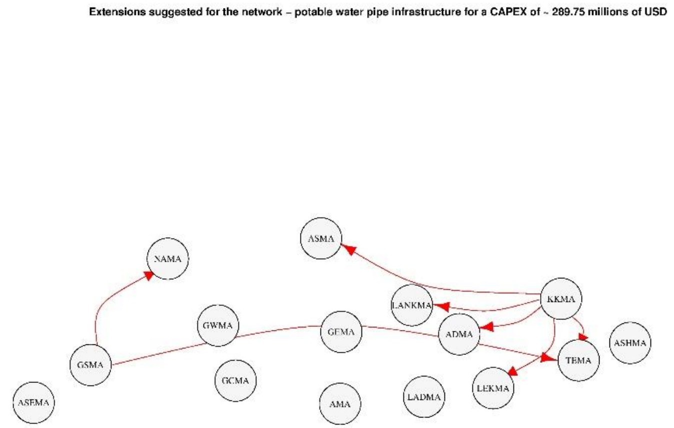


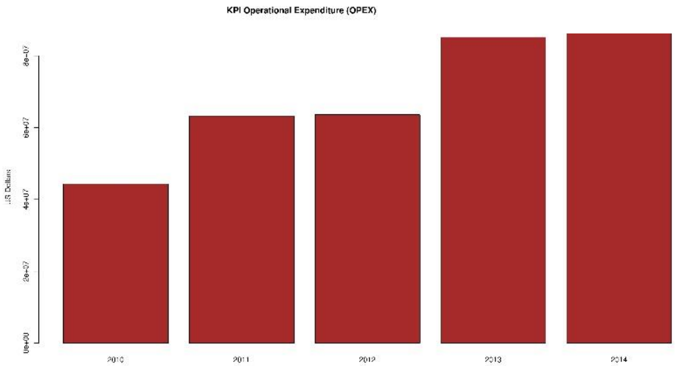
SDGs: Projection of CO_2 in 2010-2015-2020-2025-2030



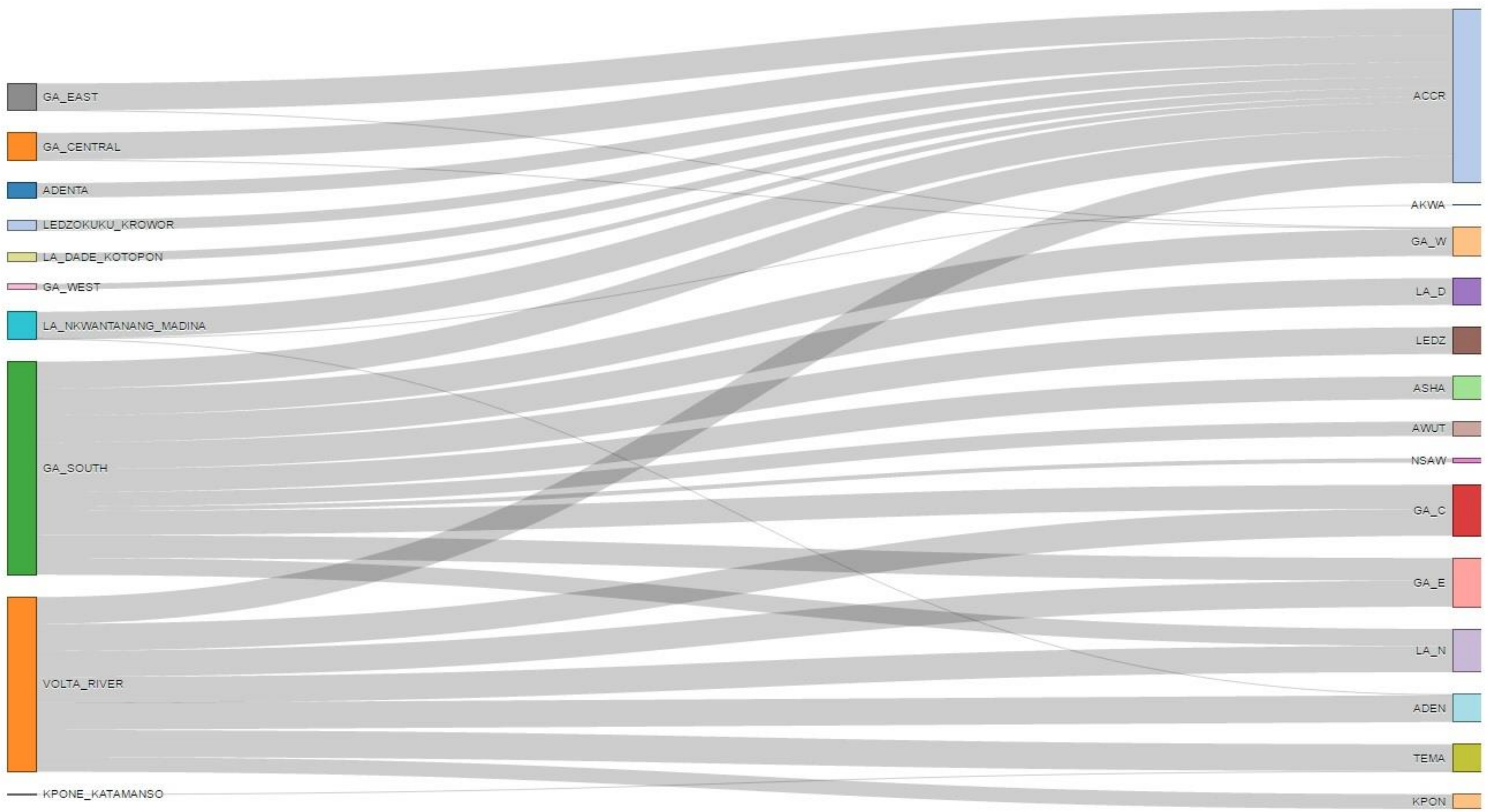
Visuals


Expansion of facilities to meet set targets, relative to year 2010
Number of facilities invested for technology type
0
20
40
60
80
100
decentralized_activated_sludge_system
ADENTA
ACCRA_METROPOLITAN
ASHAIMAN
GA_CENTRAL
GA_SOUTH
GA_WEST
GA_EAST
KPONE_KATAMANSO
LA_DADE_KOTOPON
LA_NKWANTANANG_MADINA
LEDZOKUKU_KROWOR
TEMA_METROPOLITAN
AKWAPIM_SOUTH
AWUTU_SENYA_EAST
NSAWAM_ADOAGYIRI
VOLTA_RIVER


Extensions suggested for the network – potable water pipe infrastructure for a CAPEX of ~ 289.75 millions of USD
VOLTA
ASMA
NAMA
KKMA
LANKMA
GWMA
GEMA
ADMA
ASHMA
TEMA
GSMA
GCMA
LEKMA
LADMA
AMA
ASEMA

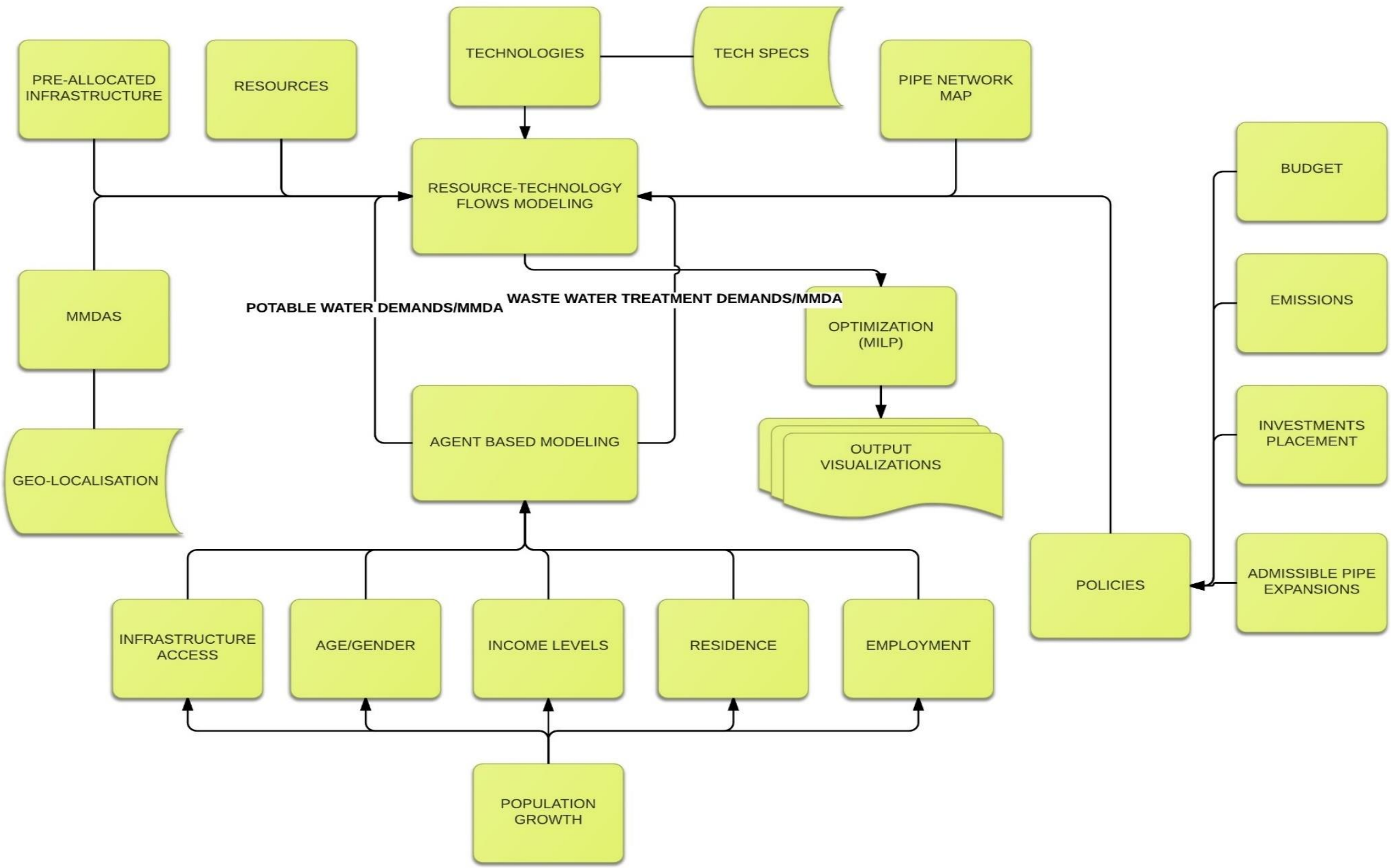

KPI Operational Expenditure (OPEX)
0e+00
2e+07
4e+07
6e+07
8e+07
2010
2011
2012
2013
2014

SDGs: 2030 optimal flows for potable water



Functionality - prototype

- Open-source and usable on laptops
- Non-sector specific (energy, water etc.)
- Scales up nicely
- Captures heterogeneity in population via agents
- Realistic representation of infrastructure/flows
- Establish outcomes for planning and projects
- Modify input data easily once set



PRE-ALLOCATED INFRASTRUCTURE
RESOURCES
TECHNOLOGIES
TECH SPECS
PIPE NETWORK MAP
RESOURCE-TECHNOLOGY FLOWS MODELING
BUDGET
MMDAS
POTABLE WATER DEMANDS/MMDA
WASTE WATER TREATMENT DEMANDS/MMDA
OPTIMIZATION (MILP)
EMISSIONS
AGENT BASED MODELING
OUTPUT VISUALIZATIONS
INVESTMENTS PLACEMENT
GEO-LOCALISATION
POLICIES
ADMISSIBLE PIPE EXPANSIONS
INFRASTRUCTURE ACCESS
AGE/GENDER
INCOME LEVELS
RESIDENCE
EMPLOYMENT
POPULATION GROWTH

Thank you for your attention!!!