



AN INTERDEPENDENT  
**INFRASTRUCTURE SYSTEMS  
PLANNING TOOL** TO SUPPORT  
LONG-TERM, NATIONAL-SCALE  
DECISION-MAKING UNDER  
UNCERTAINTY

CASE STUDY: CARIBBEAN SMALL ISLAND  
DEVELOPING STATES



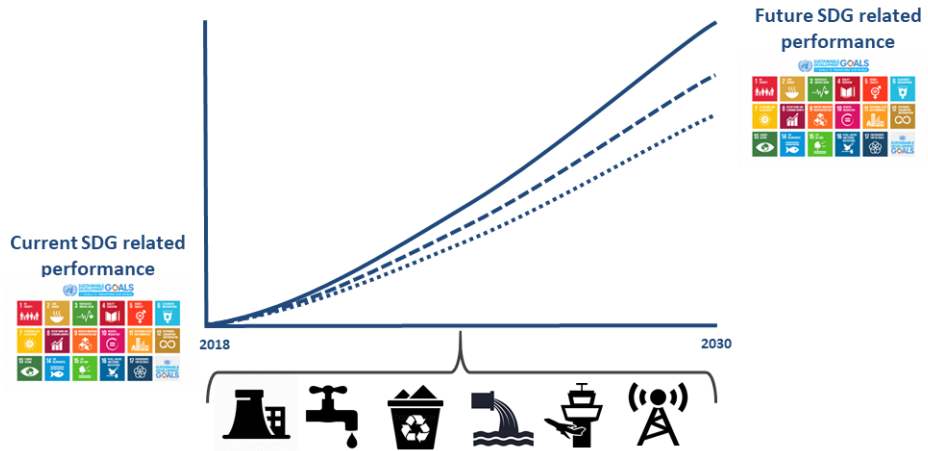
**Lena Isabel Fuldauer**

Daniel Adshead, Scott Thacker, Jim Hall

Environmental Change Institute, University of Oxford



# Need for robust decisions to unlock sustainable development



## National Infrastructure Systems *MOD*elling **NISMOD**



# *NISMOD-Int*

‘Everything should be made as **simple** as possible, but not simpler.’

Albert Einstein

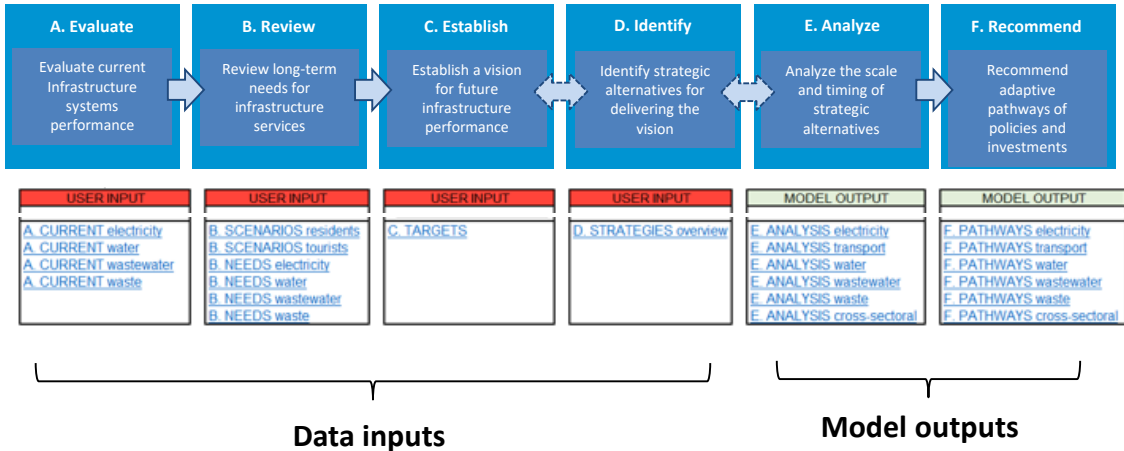


- National-scale, system-of-systems infrastructure model
- Cross-sectoral interdependencies
- Complex portfolio of interventions
- Open-source
- Transparent
- User-guided: Iterative stakeholder engagement



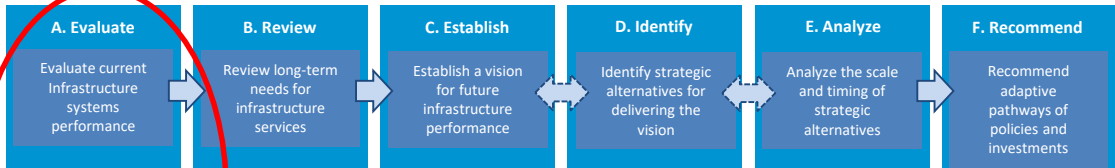
# NISMOD-Int

**Process**  
Set of steps for performing a National Infrastructure Assessment

# NISMOD-Int

**Process**  
Set of steps for performing a National Infrastructure Assessment



USER INPUT	USER INPUT	USER INPUT	USER INPUT	MODEL OUTPUT	MODEL OUTPUT
<a href="#">A. CURRENT electricity</a> <a href="#">A. CURRENT water</a> <a href="#">A. CURRENT wastewater</a> <a href="#">A. CURRENT waste</a>	<a href="#">B. SCENARIOS residents</a> <a href="#">B. SCENARIOS tourists</a> <a href="#">B. NEEDS electricity</a> <a href="#">B. NEEDS water</a> <a href="#">B. NEEDS wastewater</a> <a href="#">B. NEEDS waste</a>	<a href="#">C. TARGETS</a>	<a href="#">D. STRATEGIES overview</a>	<a href="#">E. ANALYSIS electricity</a> <a href="#">E. ANALYSIS transport</a> <a href="#">E. ANALYSIS water</a> <a href="#">E. ANALYSIS wastewater</a> <a href="#">E. ANALYSIS waste</a> <a href="#">E. ANALYSIS cross-sectoral</a>	<a href="#">F. PATHWAYS electricity</a> <a href="#">F. PATHWAYS transport</a> <a href="#">F. PATHWAYS water</a> <a href="#">F. PATHWAYS wastewater</a> <a href="#">F. PATHWAYS waste</a> <a href="#">F. PATHWAYS cross-sectoral</a>

Data inputs

Model outputs

A. CURRENT electricity
A. CURRENT water
A. CURRENT wastewater
A. CURRENT waste



NISMOD-Int\_Curacao\_v0 [Compatibility Mode] - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW TEAM

S87

## The National Infrastructure Systems Model for International contexts (NISMOD)

This Excel document encodes the analytical capability required to undertake an application of NISMOD-Int for differing countries and contexts.

The diagram below provides an outline of the methodological framework for the NISMOD-Int process and platform.

The sheets of this excel refer to the steps in the assessment process [using labels A-F] as outlined below.

More information on the NISMOD-Int process and platform can be found in Thacker et al., 2017 (see References tab for full details).

### NISMOD excel model: Process, description and contents

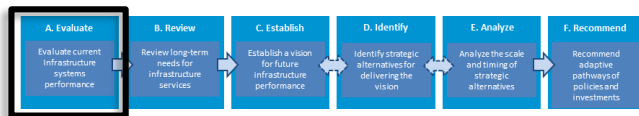
	<b>A. Evaluate</b>	<b>B. Review</b>	<b>C. Establish</b>	<b>D. Identify</b>	<b>E. Analyze</b>	<b>F. Recommend</b>
	Evaluate current Infrastructure systems performance	Review long-term needs for infrastructure services	Establish a vision for future Infrastructure performance	Identify strategic alternatives for delivering the vision	Analyze the scale and timing of strategic alternatives	Recommend adaptive pathways policies and investments
1) Process	↓					
	USER INPUT	USER INPUT	USER INPUT	USER INPUT	MODEL OUTPUT	MODEL OUTPUT
2) Description of tabs	The <b>A. CURRENT</b> tabs provide an overview of sector-specific supply and demand	The <b>B. SCENARIOS</b> tabs describe future residential and tourist forecasts, and the <b>B. NEEDS</b> tabs apply these forecasts to calculate sector-specific infrastructure needs.	The <b>C. TARGETS</b> tab illustrates different strategies for future infrastructure provision. Two default strategies are provided, and the user can specify two further ones.	The <b>D. STRATEGIES</b> overview tab provides a summary of possible investments in each sector. These can be allocated to the strategies defined by the user in <b>C. TARGETS</b> .	The <b>E. ANALYSIS</b> tabs summarize the results on the performance of strategic infrastructure investments on	The <b>F. PATHWAYS</b> tab highlights the performance of specific interventions in relation to their potential lead in time and cross-linkage with other interventions.
3) Contents	A. CURRENT electricity A. CURRENT water A. CURRENT wastewater A. CURRENT waste	B. SCENARIOS residents B. SCENARIOS tourists B. NEEDS electricity B. NEEDS water B. NEEDS wastewater B. NEEDS waste	C. TARGETS	D. STRATEGIES overview	E. ANALYSIS electricity E. ANALYSIS gas E. ANALYSIS water E. ANALYSIS wastewater E. ANALYSIS waste E. ANALYSIS cross sectoral	F. PATHWAYS electricity F. PATHWAYS gas F. PATHWAYS water F. PATHWAYS wastewater F. PATHWAYS waste F. PATHWAYS cross sectoral

LICENSE BACKGROUND CONTENTS A. CURRENT electricity A. CURRENT water A. CURRENT wastewater A. CURRENT waste B. SCENARIOS res





# A. CURRENT tab: Assessment of current infrastructure



	ID	sector	type_1	type_2	type_3	other_1	Unit	Year	value	%
<b>Supply</b>		waste	landfill			supply	tonnes/year	2016	125,373	49%
		waste	incineration			supply	tonnes/year	2016	25,100	10%
		waste	unmanaged			supply	tonnes/year	2016	10,000	4%
		waste	recycling			supply	tonnes/year	2016	89,273	35%
		waste	repurposing			supply	tonnes/year	2016	7,250	3%
			<b>Total</b>			<b>supply</b>	<b>tonnes/year</b>	<b>2016</b>	<b>256,996</b>	
<b>Annual demand</b>	waste	demand	municipal waste			population	tonnes/year	2015	63,717	25%
	waste	demand	commercial waste			population	tonnes/year	2015	136,232	53%
	waste	demand	total cruise ship-induced waste			tourist cruise	tonnes/year	2015	6,573	3%
	waste	demand	total stay-over tourists-induced			tourist stay-o	tonnes/year	2015	50,475	20%
	waste	demand								
	waste	demand								

Users may **update inputs or sources** where more recent/reliable data becomes available

Confidence level of source	Source example
high	Primary source from in-country stakeholder
med	Literature based on regional context
low	Literature based on world average Anonymous primary source

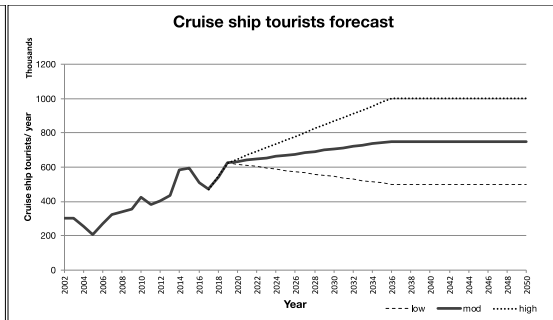
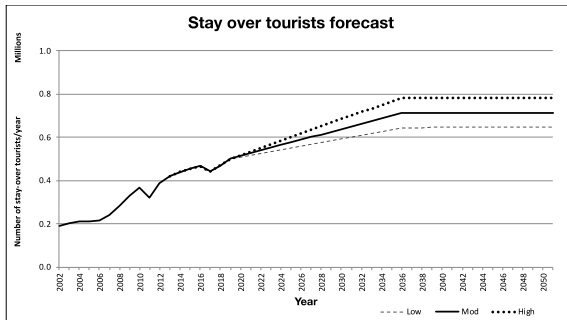
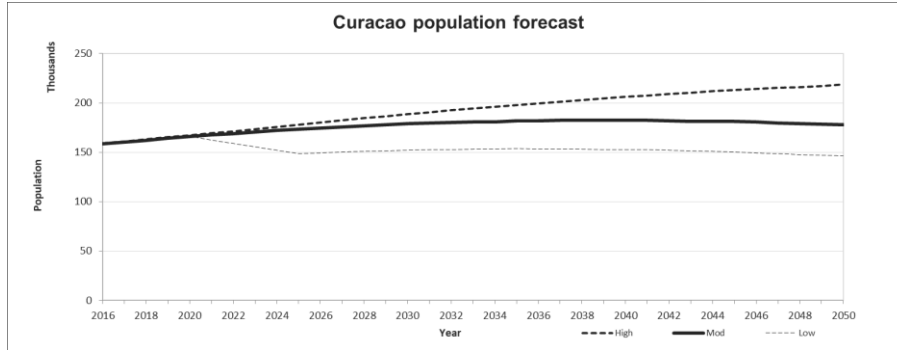
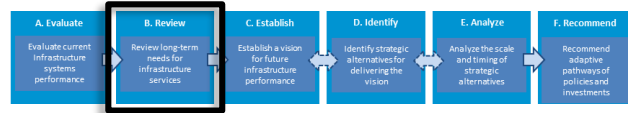




Confidence level of source		Source example
	high	Primary source from in-country stakeholder
	med	Literature based on regional context
	low	Literature based on world average

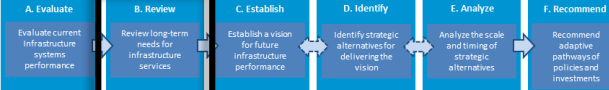


# B. SCENARIOS tab: Future infrastructure needs calculations





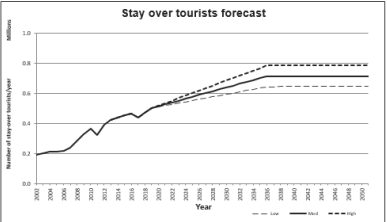
# B. SCENARIOS tab: Future infrastructure needs calculations



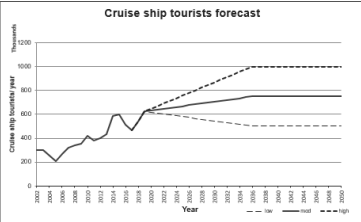
**Drivers of infrastructure needs: Tourism forecast**

Alongside the residential population, tourists are also likely to continue placing demand on infrastructure and have historically demonstrated a disproportionately larger demand for infrastructure services compared to residents. The main tourism-related drivers that affect infrastructure are projected increases in 1) stay-over tourists and 2) cruise ship tourists (see below). Three scenarios have been developed for each category of tourist – high, moderate and low – to encapsulate the range of tourism growth that could be seen on the island to the year 2035. The growth of tourists will be driven by two major transport infrastructure constructions, particularly port and airport capacity that increases visitor numbers to the island.

For further information on the methodology see the methodology and notes table (below).



**Stay over tourists forecast**



**Cruise ship tourists forecast**

**Methodology**

Parameter	Value
Peak stay-over tourist per day (Dec 2019)	12,024
Peak cruise tourists per day (Dec 2019)	2,706
Number of tourists per year (average)	2,900,000
Current capacity airport	1,600,000
Capacity airport expansion	2,900,000
Rate airport expansion	20%
1st tourists airport capacity annual	2,900,000
Additional tourists from expansion full capacity	264,816
Total cruise tourist per year (with mega pier 2)	1,000,000
Full capacity 2nd mega pier (in tourists/ day)	8,000
Additional cruise tourists from mega pier (average full capacity)	530,920

**Methodology:**

The tourist numbers (total yearly tourists, tourists stay-over nights and cruise ship tourists) from the Curacao Tourism Board (2016 and 2018) were used as baseline data (2001-2016) for the tourist projections in this tab.

The future growth of tourists was assumed to be led by two main tourists constructions characterised further in the D.STATEGIES Overview tab under 'Transport': A) the expansion of the airport terminal (increasing stay-over tourists) and B) the construction of a new mega pier (increasing cruise ship tourists) (see parameter values used on the left of this tab).

For A) the expansion of the airport terminal, the following considerations have been made: the airport expansion to be finalised by the end of 2018 provides capacity for an additional 900,000 arrivals (Airport Tech, 2017). Each stay-over tourists is expected to stay for an average of 9 nights (see Curacao Tourism Board, 2016). Currently, 25% of the yearly airport capacity can be attributed to tourists (see cell C12). As such, the additional tourists from the terminal expansion (under full capacity) is given in cell C13. Three scenarios have been constructed, including 1) a low infrastructure-led growth rate, which assumes that 50% of the total tourist capacity of the airport terminal is used by 2035, 2) a medium infrastructure-led growth rate, assuming that 75% of the total tourist capacity of the airport terminal is used by 2035, and 3) a high infrastructure-led growth rate, assuming that the full capacity for tourists is used by 2035. All three scenarios consist of a gradual increase of tourists to that capacity by 2035. After 2035, the growth rate is assumed to be 0%. For the peak calculations, the peak tourist month (December has been utilized).

For B) the construction of a second cruise terminal, the expected total capacity (including both cruise terminals) is expected to be 1 million cruise tourists per year (Business Curacao 2015). Each cruise ship tourists is expected to stay for an average of 1 day. Three infrastructure-led cruise-ship scenarios have been developed: 1) a low growth rate, assuming 50% of the total cruise ship capacity built in 2018 is utilized by 2035, 2) a medium growth rate, assuming that 70% of the capacity is utilized by 2035 and 3) a high growth rate, assuming that the full capacity is utilized by 2035. For the peak calculations, the peak tourist month (December has been utilized). For the calculations of tourists until 2018, the historic average growth rate of the past 5 years was applied for stay-over tourists (7%) and cruise ship tourists (12%).

**Assumptions:**

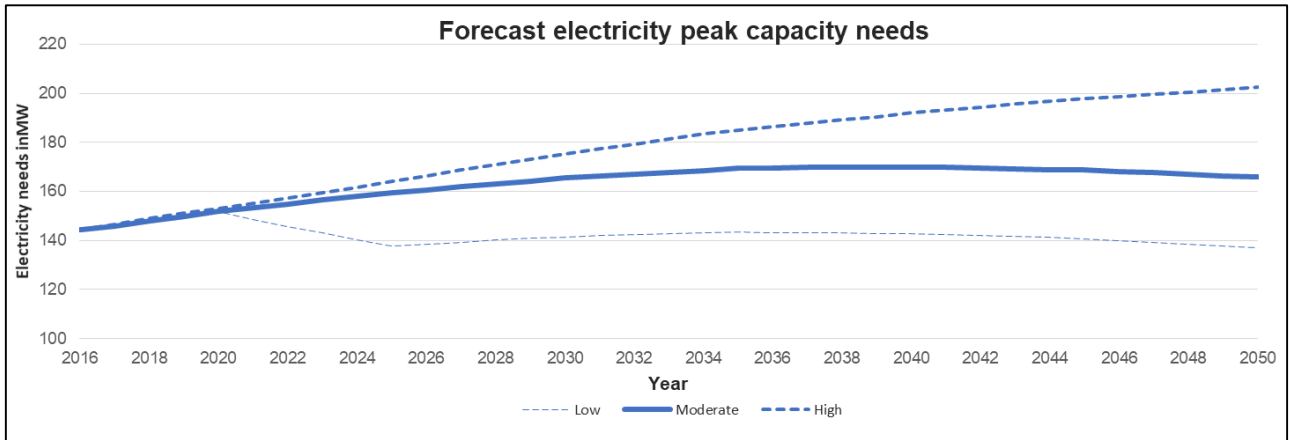
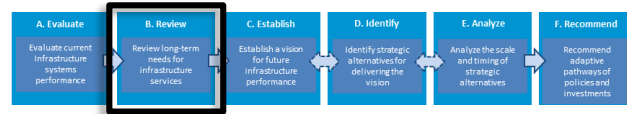
The trend indicating a decrease in tourists staying in traditional hotels and an increase in tourists staying at privately owned apartments is considered to have a null effect on infrastructure needs. The trend indicating an increase in tourists staying in traditional hotels and a decrease in tourists staying at privately owned apartments is considered to have a null effect on infrastructure needs.

Confidence level of source	Source example
High	Press releases from ministry & stakeholders
Med	Government Board of regional government
Low	Information based on social media coverage
Very Low	Information based on social media coverage

**Navigation:** A. CURRENT waste | B. SCENARIOS residents | B. SCENARIOS tourists | B. SCENARIOS (aggregated) | B. NEEDS electric

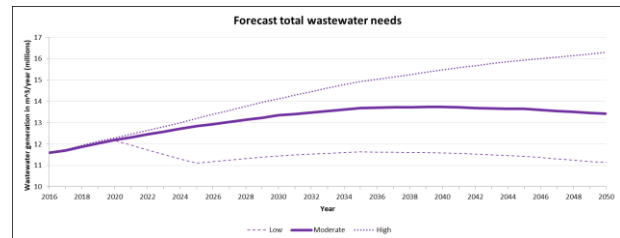
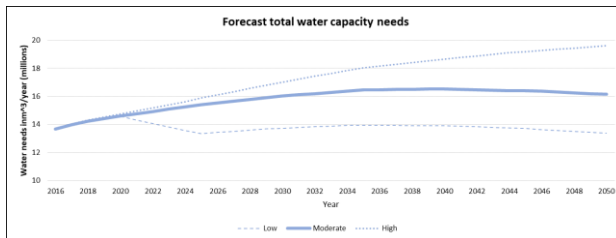
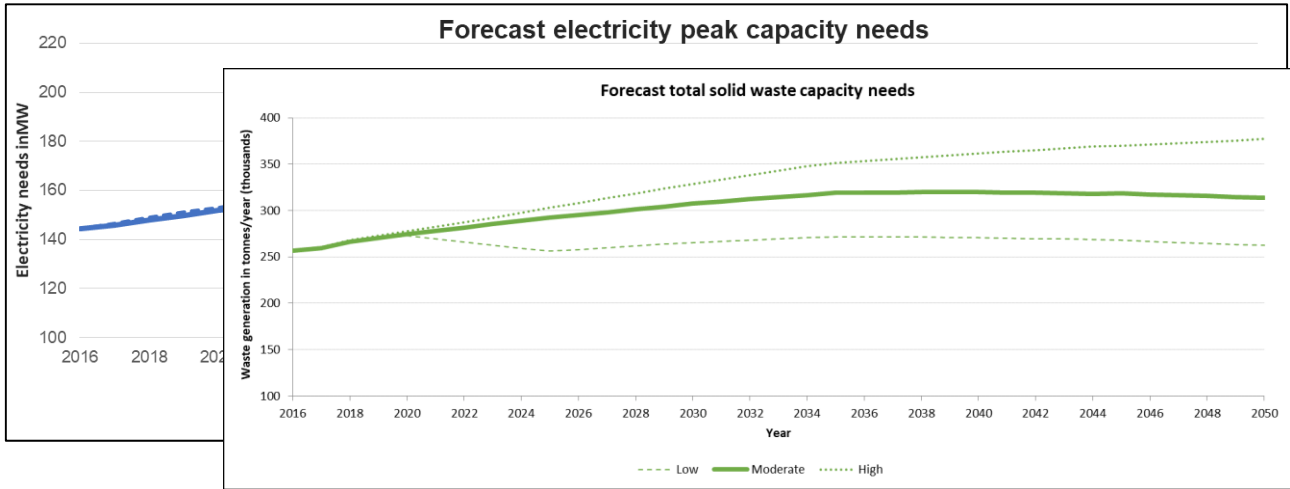
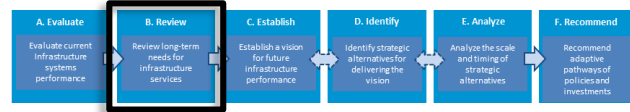


# B. SCENARIOS tab: Future infrastructure needs



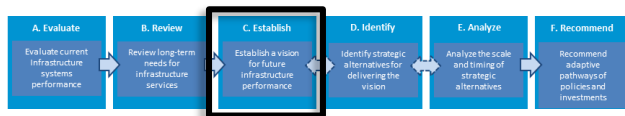


# B. SCENARIOS tab: Future infrastructure needs





# C. TARGETS tab: Setting portfolios and visions

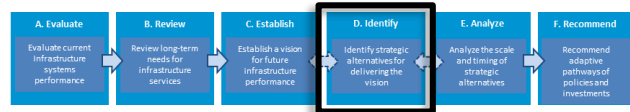


Strategy = portfolio of investments

- Can represent a target, e.g. ‘Environmental Action’

Users can establish their own vision for their strategies by inputting a relevant **name**

USER INPUT REQUIRED	
strategies (default/user)	strategy name
EBI_1	inaction
EBI_2	EBI strategy
User_1	User strategy 1
User_2	Example Strategy

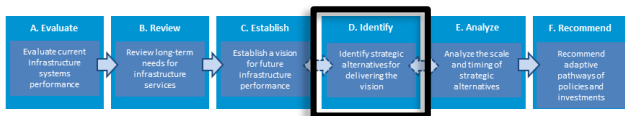


Users can select which investments are included in a strategy. Here, 'Example Strategy' is focused on 'Environmental Action'.

Sector	Strategic alternatives				Strategy mapping	
	ID	sector_1	type_1	type_2	USER STRATEGY 1	EXAMPLE STRATEGY
Energy	ene1	electricity	supply	Dual fuel diesel plant	0	1
	ene2	electricity	supply	SWAC	0	0
	ene3	electricity	supply	Solar microgeneration	0	1
	ene4	electricity	supply	Wind generation	0	0
	ene5	electricity	supply	Waste-to-energy plant	0	0
	ene6	electricity	supply	SWAC full-scale	0	0
	ene7	electricity	supply	Solar microgeneration	0	1
	ene8	electricity	supply	OTEC plant	0	0
	ene9	electricity	supply	Solar microgeneration	0	1
	ene10	electricity	efficiency	Technical grid improvements	0	0
	ene11	electricity	demand	Consumption reduction, domestic (15%)	0	1
	ene12	electricity	demand	Consumption reduction, service sector (10%)	0	1
	ene13	electricity	demand	Consumption reduction, domestic (25%)	0	1
	ene14	electricity	efficiency	Technical grid improvements	0	1



# D. STRATEGIES tab: Adding new interventions

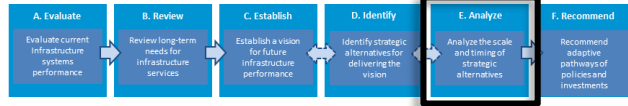


Users can add new investments, which should be allocated a 'Year' and 'Value'.

Sector	Strategic alternatives					Capacity/ demand			Cost		Carbon		
	ID	sector_1	type_1	type_2	type_2_size	Unit	Year	Value	CAPEX (\$)	OPEX (\$/t/year)	Id	CO <sub>2</sub> eq	Unit
Energy	ene13	electricity	demand	Consumption reduction, domestic (25%)	large	GWh	2036	-177			28	-43,493	t CO <sub>2</sub> eq/year
	ene14	electricity	efficiency	Technical grid improvements	large	GWh	2032	-40			28	-9,836	t CO <sub>2</sub> eq/year
	ene15	electricity	supply	Solar expansion	large	GWh	2036	50			10	2,400	t CO <sub>2</sub> eq/year

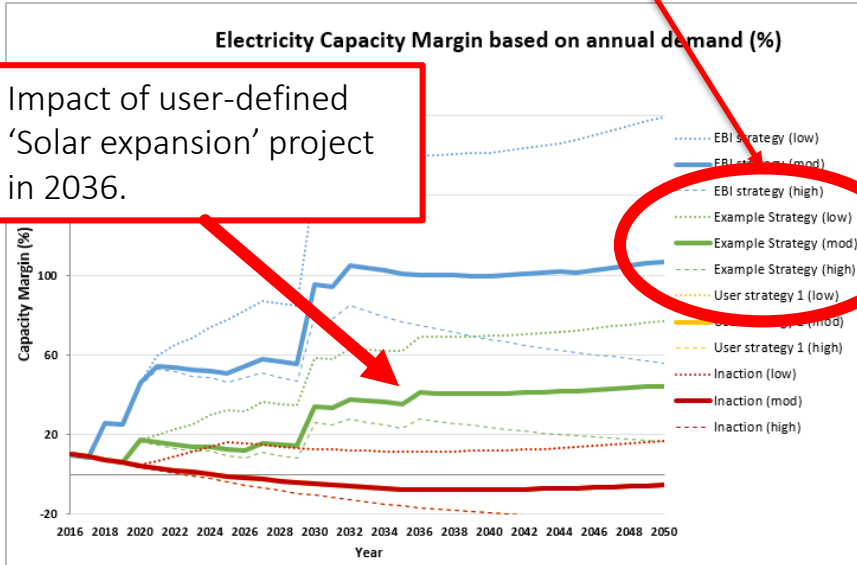


User strategies can be compared with other pre-defined strategies.

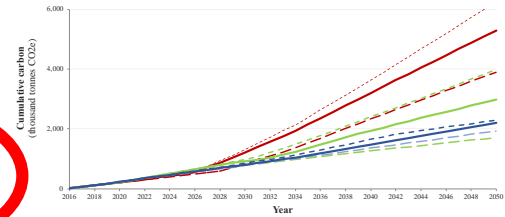


**Electricity Capacity Margin based on annual demand (%)**

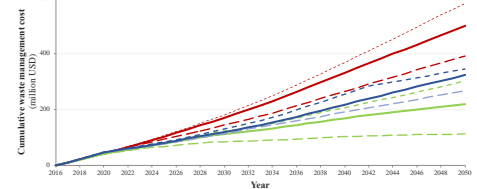
Impact of user-defined 'Solar expansion' project in 2036.

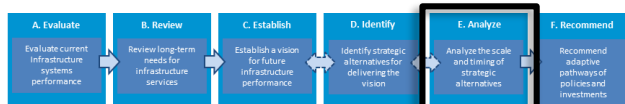


**Carbon**



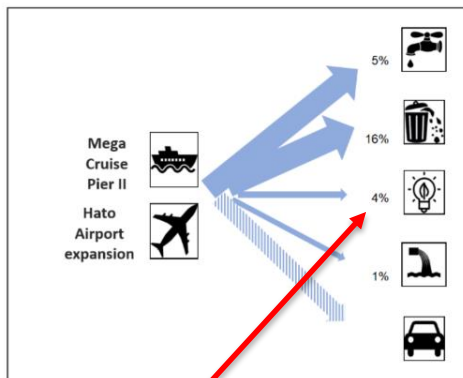
**Cost**





## 1) INFRASTRUCTURE SUPPLY INTERDEPENDENCY - ADDING CROSS-SECTOR DEMAND: Tourism - the impact of port and airport capacity expansion

These calculations assume that the full capacity of the two constructions are met (including 1) the second Mega Pier for cruise ship tourists and 2) the airport terminal expansion for tourists.



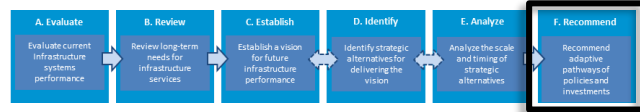
### Methology calculations

**USER UPDATE**

Capacity installation tourism	Electricity demand (peak)	Water demand	Waste demand	Wastewater demand
Additional tourists from expansion	264,815 per stay-over tourist	0.000013 GWh/per/year	Per stay-over tourist	0.01 tonnes/day
additional tourist nights	530,502 per tourist	0.000013 GWh/per/year	Per cruise-ship tourist	0.01 tonnes/day
additional cruise tourists	530,502			
Capacity used	100%			

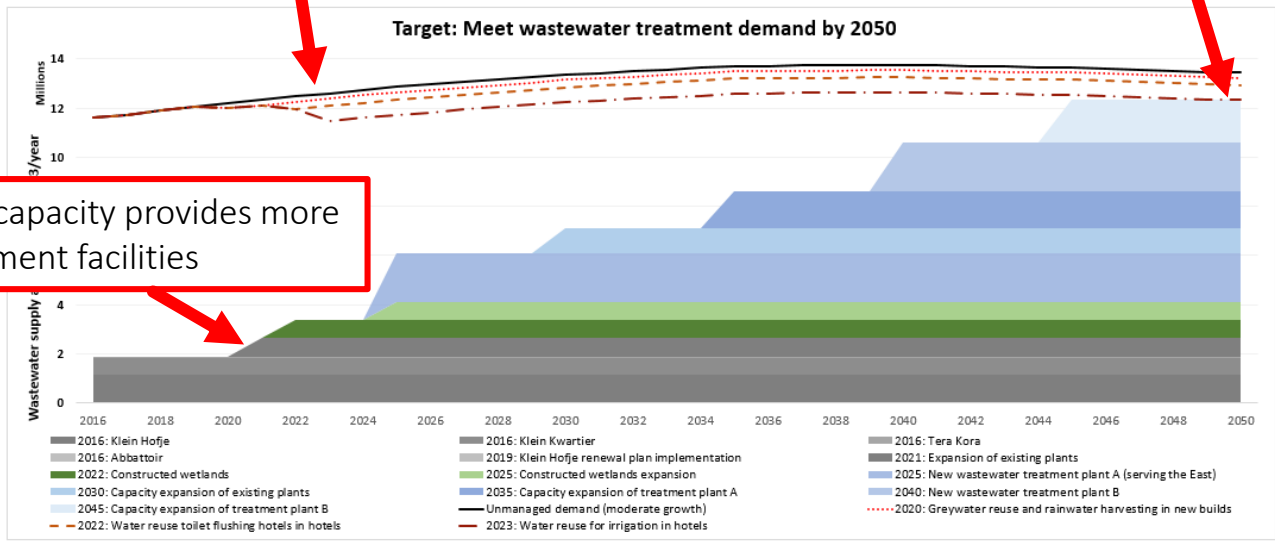


# F. DECISIONS tab: Potential quick wins



Demand management measures reduce demand

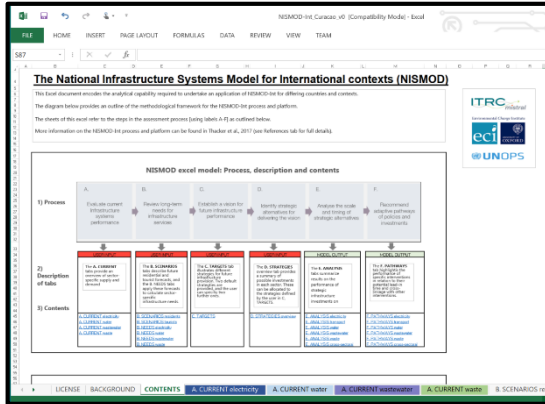
Target is met in 2050



New capacity provides more treatment facilities



## Model



**The National Infrastructure Systems Model for international contexts (NISM0D)**

This Excel document encodes the analytical capability required to undertake an application of NISM0D for a differing country and context. The steps in below provide an outline of the assessment process for the NISM0D for curacao used platform.

The views of this excel can be seen in the assessment process (using tables A-F) outlined below.

More information on the NISM0D for process and platform can be found in (Fisher et al., 2017) (see references tab for full details).

**NISM0D excel model: Process, description and contents**

	A	B	C	D	E	F
1) Process	Establish current infrastructure performance	Review transport assets for performance	Identify a vision for transport infrastructure performance	Identify specific interventions for delivering the vision	Analyze the scale and timing of interventions	Forecast model infrastructure performance
2) Description of tabs	Tab A: Current infrastructure performance	Tab B: Infrastructure assets for performance	Tab C: Vision for transport infrastructure performance	Tab D: Specific interventions for delivering the vision	Tab E: Scale and timing of interventions	Tab F: Infrastructure performance forecast
3) Contents	Current infrastructure performance	Infrastructure assets for performance	Vision for transport infrastructure performance	Specific interventions for delivering the vision	Scale and timing of interventions	Infrastructure performance forecast

## User-guide

**License and general information**

The NISM0D-for-curacao model is licensed under a **Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License**. Please see the following website for complete license details: <http://creativecommons.org/licenses/by-nc-sa/4.0/faq/#code>

**Citation**

Fuldauer, J., Akhond, D., Tucker, S., Hilkford, A.J. 2018. Long term strategic infrastructure model for international contexts. Oxford University, Oxford, UK.

**Introduction**

This document provides guidance for novice users of NISM0D for Curacao, designed to be used in conjunction with the Excel model provided separately entitled "NISM0D\_for\_Curacao\_v0.0.xlsx". The model has been developed as part of the Evidence-Based Infrastructure Assessment carried out on behalf of the Ministry of Traffic, Transport and Urban Planning of Curacao, UNOPS, and the Infrastructure Transition Research Consortium (ITRC), having involved a large number of stakeholders in the country. It is an early towards building long-term, cross-sectoral knowledge and capabilities for infrastructure planning and operation.

As part of this evidence-based Infrastructure Assessment, the model can provide useful insights into the cross sectoral performance of Curacao's infrastructure systems. The process involves a number of steps (A-F), as follows:

	A	B	C	D	E	F
1) Process	Establish current infrastructure performance	Review transport assets for performance	Identify a vision for transport infrastructure performance	Identify specific interventions for delivering the vision	Analyze the scale and timing of interventions	Forecast model infrastructure performance
2) Description of tabs	Tab A: Current infrastructure performance	Tab B: Infrastructure assets for performance	Tab C: Vision for transport infrastructure performance	Tab D: Specific interventions for delivering the vision	Tab E: Scale and timing of interventions	Tab F: Infrastructure performance forecast
3) Contents	Current infrastructure performance	Infrastructure assets for performance	Vision for transport infrastructure performance	Specific interventions for delivering the vision	Scale and timing of interventions	Infrastructure performance forecast

For Steps A-D, **users are encouraged to input values** for specific variables, or to update related information where appropriate. Where such inputs are expected, cells are coloured a shade of red.

The user inputs are used in two ways:

- To update and improve the confidence of available data (Steps A-D)
- To develop future vision of infrastructure performance, and devise strategies which reflect specific investments and policies (Steps C and D)

These user inputs are described in more detail below, using examples from the various tabs. Screenshots are used to help the user identify cells or locations where they are encouraged to input new values. Specific sectoral examples are given below, although the process is applicable to all sectors in the same step.

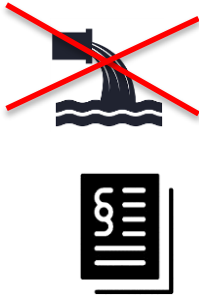
Note that screenshots may have been adapted for clarity, and might not exactly replicate the actual cells in the various tabs.



## Impacts to date on two levels:

Specific decisions/ legislations

Policy process





## Conclusions

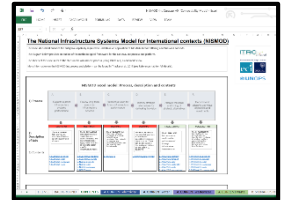
Advancing cross-sectoral, transparent, national-scale infrastructure planning under uncertainty

- De-politicize
- Underpinned by data
- Transparent
- Tool maintained by relevant stakeholders in-country
- Future: St. Lucia, Grenada, ...

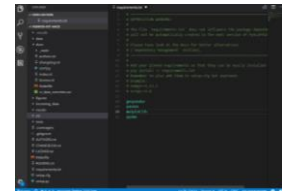
## Next steps

### Excel model

- Additional functionality
- Other sectors
- Social infrastructures
- Ongoing maintenance



### Python model





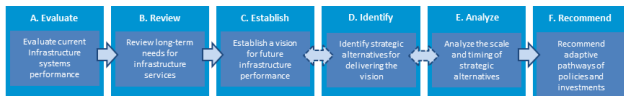
# Questions?

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Environmental Change Institute  
University of Oxford



# E. ANALYSIS tab: Cross-sectoral interdependencies



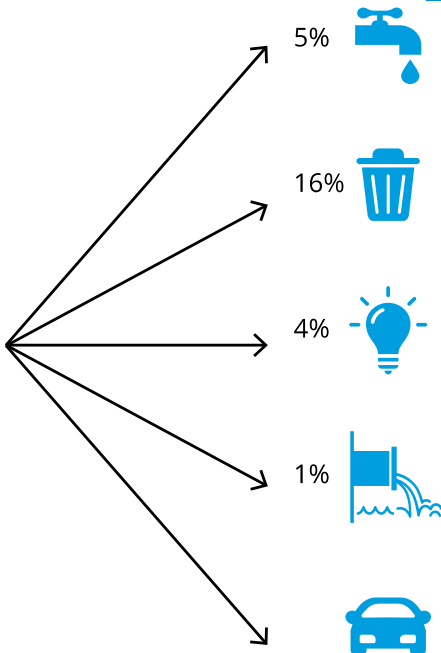
Infrastructure demand driver



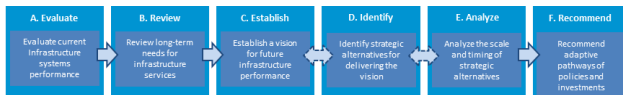
Mega Cruise Pier II



Hato Airport expansion







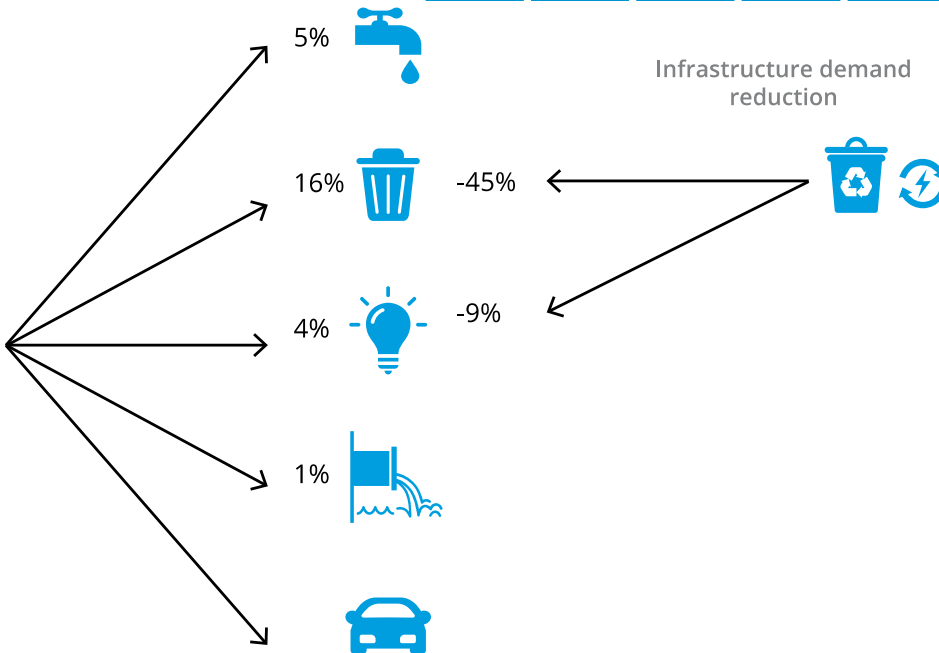
Infrastructure demand driver

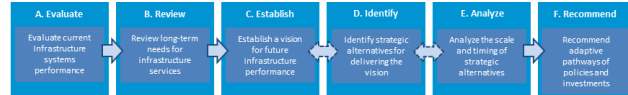


Mega Cruise Pier II



Hato Airport expansion





Infrastructure demand driver



Mega Cruise Pier II



Hato Airport expansion

