nature sustainability

Supplementary information https://doi.org/10.1038/s41893-024-01395-7

Sustainable urban transformations based on integrated microgrid designs

In the format provided by the authors and unedited

Supplementary Material

Illustration of the impact of Hurricane Florence on power customers in New Hanover County. Based on the local utility's detailed knowledge of the power outages that occurred, affected areas with outage duration longer than twelve hours are displayed in Fig. 1.

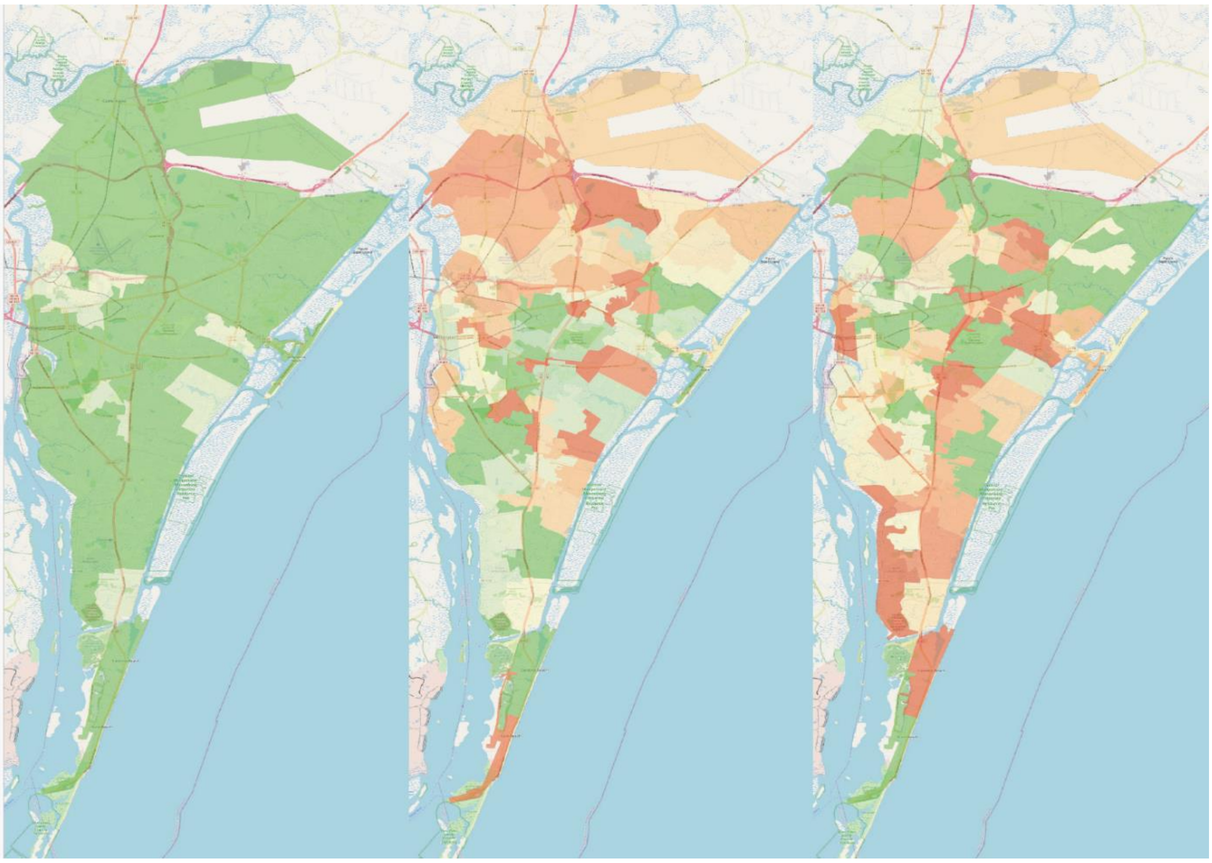

Figure 1 ***Power failures.*** *Aggregated view on power failure induced impacts immediately following the landfall of hurricane Florence in percentage of all customers affected per supply zone, darker red indicates that more were affected. First twelve hours (left) starting at 13th September 2018, second twelve (center) and third twelve hours (right).*

Criticality and normalized peak load of critical infrastructure:

Table 1 Critical infrastructures and those that is very relevant in the immediate aftermath of a shock event dealing with relief, health and safety (RHS), are marked with a cross.

Critical infrastructure type	RHS	Criticality	Peak Load
Airport		0.7	1.0
Bus		0.3	0.1
Communication	X	0.8	0.1
Community Lifeline Facility	X	1.0	0.3
Emergency Medical Services	X	1.0	0.2
Emergency Shelter	X	1.0	0.3
Ferry		0.5	0.2
Fire Department	X	1.0	0.2
Gasoline		0.8	0.3
Grocery		0.8	0.4
Hazardous Waste Site	X	0.9	0.6
Highway		0.7	0.2
Hospital	X	1.0	1.0

Manufactured Gas Plant		0.8	0.3
Medical Facility	X	0.9	0.2
Nursing Homes	X	0.9	0.5
Oil Infra		0.8	0.4
Pharmacy	X	0.9	0.2
Police Station	X	0.9	0.2
Port		0.7	0.3
Potable Water Infra	X	0.9	0.6
Rail		0.7	0.2
Religious Place		0.2	0.1
Roads		0.7	0.3
School		0.7	0.3
Waste Water	X	0.9	0.8

Evolutionary Algorithm (EA) based studies:

The parameter- and coefficient choices for our three case studies are given in the following table:

Table 2 Applied metric settings for identifying optimal microgrid planning solutions that are only economic (case F and $s_1 = 0.5$), or economic, equitable and urban resilient (case R and $s_1 = 0.5$).

Case	Max. number of microgrids	R_1	R_2	F_1 $s = 0.9$	F_2 $d = 0.9$	F_3	SST	SPV	FD $s_1 = 0.5$
F	3	0	0	0.175	0.2	0.25	0.15	0.15	0.075
R	8	0.4	0.15	0.05	0.05	0.15	0.05	0.05	0.1

For the comparatively low complexity of our problem, only 64 building blocks, our EA is characterized as follows:

1. The initial population consists of connected clusters.
2. The offspring result from an operator that mutates along the topological boundary of connected cluster components, which allows preservation of connectivity to some degree.

In addition, a control parameter was used that allows the number of clusters to be reduced or maintained. The following technical EA parameters were used and stability results were observed:

Table 3 Evolutionary Algorithm parameter setting for our studies for finding optimal solutions per case and corresponding SVI data from 2018.

Case	Number of microgrids may decrease	Final number of microgrids	Initial population size	Breeding	Mutation rate	Max. number of iteration steps, last change	Fitness
F		3	150,000	0.075	0.075	10,635, 652	0.7725473
R	X	6	250,000	0.075	0.075	4,129, 2,536	0.5515835