Chapter 5

Conclusion and Policy Recommendation

An optimal small- and medium-scale LNG delivery and cost study in the Philippines was conducted in the following way.

1. The electricity demand distribution and LNG demand in 2040 were estimated and LNG terminal locations selected.
2. The optimal LNG delivery system was determined by static simulation using a linear programming model.
3. With reference to the static simulation results, the costs of various LNG delivery scenarios, including the typhoon strike scenario, were compared using dynamic simulation to model LNG barge operation.

In Chapter 2, the study first estimated the distribution of electricity demand in the Philippines by province. The results were used to identify the possible locations of GPPs in 2040. Then, the necessary amount of LNG to run the assumed number GPPs was calculated. To do this, the study identified the concentration of electricity demand, and thus, suitable places for siting GPPs and LNG receiving terminals.

In the Luzon power grid area, all the three possible LNG receiving terminals are estimated to have enough demand to become importing terminals (primary terminals). Therefore, these LNG supplies are excluded from the analysis.

In the Visayas power grid area, Cebu, Tagbilaran, and Tacloban are identified as candidate locations for bulk-breaking LNG receiving terminals. Of the three, Cebu is estimated to have the largest LNG demand.

In the Mindanao power grid area, Zanboanga, Iligan, Bislig, Surigao, and General Santos are selected as possible locations for bulk-breaking LNG receiving terminals.

In Chapter 3, the study compared several different solutions, in terms of location of LNG terminals, type and scale of facilities, and transportation models. Based on the distribution of demand, the pattern of demand near each port, and the physical conditions of the port, our mixed integer programming model indicated the most efficient (i.e. meeting the demand at minimum cost) solution for Visayas and Mindanao by 2040.

According to the results of the model and comparison of several scenarios, it is recommended that Cebu and Zamboanga are developed as the primary LNG receiving terminals, with the capacity to redistribute LNG to other demand centres in the southern districts, applying FSRU solutions. An optimal combination of large and small barges operating a hub-and-spoke transportation model is the solution with the minimum total system costs.

In Chapter 4, the dynamic simulation study identified key factors for small- and medium-scale LNG deliveries to the subordinate terminals. They include the capacity of the LNG barges and storages.

To minimise costs, it is essential to reduce the number of LNG deliveries to the subordinate terminals by using large barges. The application of large-capacity storage is crucial for mitigating disruption to LNG deliveries to the islands due to natural disasters. To avoid a shortage of LNG tanks, each subordinate terminal should have a large tank at its site, but this increases capital costs. A combination of six large-capacity LNG barges (30,000m^3) and six large-capacity LNG storages (50,000m^3) could avoid tank shortages due to typhoons. The operating cost of the LNG barges and storages is estimated at $30.1 million.

The rate of operation of the third and fourth barges allocated to Cebu is too low, however. Operating the LNG tankers more wisely could decrease the number of LNG barges needed at the Cebu primary terminal.

Appendix. Patterns of Operation in Scenarios 5 and 6

Tables A1 and A2 present the number of small barges and large barges delivery to each port from the two primary terminals chosen in Scenario 5.

Table A1. Weekly Delivery Schedule by Small Barge: Scenario 5 (number of barges)

To	From	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Tag	Ceb	2	4	2	3	3	4	1	3	4	1	3	4	2	2	3	4	2	3	2	4	2	3	4	1	4	2	2	5	2	2	4	3
Tag	Zam	1																															
Tac	Ceb	1																															
Ili	Ceb	3	3	3	3	2	3	4	2	3	3	4	1	3	3	4	1	3	2	3	3	3	4	1	4	3	2	3	2	3	3	3	2
Ili	Zam										1							2									1						
Bis	Ceb	3	2	2	2	2	2	2	3	2		2	2	2	2	2	2	2		2	2	4		2	3	2		3	2	2	2	2	3
Sur	Ceb				1																												
San	Zam										1																						

To	From	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Tag	Ceb	3	1	3	4	3	3	2	3	3	3	2	2	3	2	3	3	4	3	1	3
Tag	Zam																				
Tac	Ceb	3	4	2	3	2	4	3	2	2	4	3	2	2	3	4	2	3	2	3	3
Ili	Ceb	1											3							1	2
Ili	Zam		2	2	2	2	2	2	2	4	2		1		2	2	4	2		1	
Bis	Ceb																				
Sur	Ceb																				1
San	Zam																				

Bis = Bislig, Ceb = Cebu, Ili = Iligan, San = General Santos, Sur = Surigao, Tac = Tacloban, Tag = Tagbilaran, Zam = Zamboanga.

Source: Author.

Table A2. Weekly Delivery Schedule by Large Barge: Scenario 5 (number of barges)

To	From	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Bis	Ceb	1		1		1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1	1		1
Bis	Zam		1																														
Sur	Ceb	1	1	1	1	1		1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1	1	1		1	1	1	1
San	Zam	1	1	1	1	1		1	1	1		1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1	1		1

To	From	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Bis	Ceb	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1	1	
Bis	Zam																				

Sur	Ceb		1	1	1	1		1	1	1	1	1		1	1	1	1		1	1	
San	Zam	1	1	1		1	1	1	1	1		1	1	1	1		1	1	1	1	

Bis = Bislig, Ceb = Cebu, Ili = Iligan, San = General Santos, Sur = Surigao, Tac = Tacloban, Tag = Tagbilaran, Zam = Zamboanga.

Source: Author.

In the case of milk-run delivery, our model optimises the amount of delivery, rather than the number of ship deliveries (since each ship does not necessarily unload equal amounts of LNG at each call to the port) that reach a port from a certain primary port or non-primary port. The benefit of such practice is for the consideration of reducing the model from a non-linear programming problem to a linear programming one, so as to save the computing resources needed which is typically beyond that of a personal computer. Tables A3 and A4 present the results of the amount of delivery by small barges and large barges to each non-primary port.

Table A3. Schedule of Delivery in Scenario 6 as Amount of Delivery Reached by Small Barges (in 52 weeks)

To	From	Via	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
g	m	g			8.4		6.6							0.1	2.15				8.95	9.25	.6	5.8		0.5
g	m	c	0.6	6.2		15	2.8	0.6	8.4	8.7	2.1	1.6	4.7	4.9	9	7.45		1.6		1.8	7	0.6	0.6	8.9
g	m		4.4	8.8	6.6	6.6			13.2	6.6	5		11.6			11.4	8.4							
c	m	g			8.4														8.95					
c	m	c	7.2	6.2		15	15	0.6	8.4	15	2.1	1.6	8.4	1.5	9	7.45	3.2	1.6		1.8	5	0.6	0.6	8.9
c	m			6.6	6.6			11			12.9				8.85				12.65			5.2	11	2.2
	m	g					6.6							0.1	2.15					9.25	.6	5.8		0.5
	m	c	6.6				2.2			6.3			3.7	6.6			3.2				8			

Ili	Zam	Ili	4.4	15.4	13.2	6.6		11	13.2	6.6	17.9		11.6		8.85	11.4	8.4		12.65			5.2	11	2.2

To	From	Via	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Tag	Zam	Tag	1.5	6.3	5.3	5.2	6.6	3.3	6.6	6.6	13.2		6.6	6.6	5	6.6	9.5		1.5	11	10.6			15
Tag	Zam	Tac		15.3	13.6	6.2	15	2.9	15	10.6	1.8	5.9	10.9	15	10	4.9	9	14.5		10.6		9.65	10.6	
Tag	Zam	Ili																0.5			11		10.05	
Tac	Zam	Tag																			10.6			15
Tac	Zam	Tac		15.3	13.6	6.2	15	2.9	15	15	8.4	21.6	10.9	15	10	15	10.5	19.5	15	10.6		9.65	10.6	
Tac	Zam	Ili	14.7			10.2		12.1					4.1		5							11	0.95	6.6
Ili	Zam	Tag	1.5	6.3	5.3	5.2	6.6	3.3	6.6	6.6	13.2		6.6	6.6	5	6.6	9.5		1.5	11				
Ili	Zam	Tac								4.4	6.6	15.7				10.1	1.5	5	15					
Ili	Zam	Ili	14.7			10.2		12.1					4.1		5			0.5			11	11	11	6.6

To	From	Via	45	46	47	48	49	50	51	52
Tag	Zam	Tag	15	1.9	2.7	17.2	10.6	10.6	10.6	15
Tag	Zam	Tac		13.1						

Tag	Zam	Ili					6.6	3.2		
Tac	Zam	Tag	4.35		2.7	10.6	10.6	10.6	10.6	4.5
Tac	Zam	Tac	4.75	13.1			4.4			0.5
Tac	Zam	Ili		6.6		4.4		7.8	11	
Ili	Zam	Tag	10.65	1.9		6.6				10.5
Ili	Zam	Tac	4.75				4.4			0.5
Ili	Zam	Ili		6.6		4.4	6.6	11	11	

Bis = Bislig, Ceb = Cebu, Ili = Iligan, San = General Santos, Sur = Surigao, Tac = Tacloban, Tag = Tagbilaran, Zam = Zamboanga.

Source: Author.

Table A4. Schedule of Delivery in Scenario 6 as Amount of Delivery Reached by Large Barges (in 52 weeks)

To	From	Via	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Bis	Ceb	Bis					6.00			6.75										4.85			5.60
Bis	Ceb	Sur	6.75	6.75	6.75	6.75		1.95								4.30	6.75			1.90	5.10		
Bis	Ceb	San													3.50			6.75				2.50	
Bis	Zam	Bis	3.35	4.25	11.30		4.30				2.50						9.90		9.60	4.25	11.90		5.60
Bis	Zam	Sur	0.90						11.90	11.00	8.40		3.40		5.00							2.50	
Bis	Zam	San						11.90		0.90		11.10	5.80		8.50								
Sur	Ceb	Bis																					
Sur	Ceb	Sur	6.75	6.75	6.75	6.75		1.95	6.75			6.75	6.75			4.30	6.75			1.90	5.10	4.25	1.15
Sur	Ceb	San						4.8						6.75	3.25	2.45					1.65		
Sur	Zam	Bis			1.80														9.60	4.25	4.25		5.60
Sur	Zam	Sur	0.90			11.90			11.90	11.00	8.40		3.40		5.00		2.00					6.75	
Sur	Zam	San	7.65	7.65	0.60		7.60				2.60	0.80	4.30					11.90	2.30	3.05			4.25
San	Ceb	Bis					6.00			6.75										4.85			5.60
San	Ceb	Sur							6.75			6.75	6.75									4.25	1.15
San	Ceb	San						4.80						6.75	6.75	2.45		6.75			1.65	2.50	
San	Zam	Bis	3.35	4.25	9.50		4.30				2.50						9.90				7.65		
San	Zam	Sur				11.90											2.00					4.25	
San	Zam	San	7.65	7.65	0.6		7.600	11.90		0.90	2.60	11.90	10.10		8.50			11.90	2.30	3.05			4.25

To	From	Via	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Bis	Ceb	Bis					6.75	6.75	2.50		6.75					6.75		5.00	3.30	4.73		6.75	
Bis	Ceb	Sur			2.75				2.50	4.20				1.25	4.63								
Bis	Ceb	San		6.75								3.40					6.75	1.75			6.75		6.75
Bis	Zam	Bis	3.15	13.50		2.50		8.55		4.20		4.25		4.25	6.38	13.50	7.65					0.90	2.58
Bis	Zam	Sur					0.90				7.65	7.65	1.20							4.73	7.18		1.68
Bis	Zam	San	7.65		5.00	2.50	7.65				0.90		1.20	5.50			0.85				0.43		
Sur	Ceb	Bis					6.75	6.75										5.00				6.75	
Sur	Ceb	Sur			6.75	6.75			4.25	4.20		3.35		1.25	4.63				3.45				
Sur	Ceb	San	6.75							2.55			6.75	5.50	2.13					2.03			
Sur	Zam	Bis	3.15	13.5		2.50		0.90						4.25		11.00	7.65					0.90	
Sur	Zam	Sur			1.75	1.75	0.9		6.75		11.00	7.65	1.20		4.25		3.40	13.50		8.98	7.18		3.35
Sur	Zam	San	1.10				3.35	3.35		4.25			3.05								3.83	11.00	
San	Ceb	Bis							2.50		6.75					6.75			3.30	4.73			

San	Ceb	Sur			4.00	6.75			1.75			3.35							3.45				
San	Ceb	San	6.75	6.75						2.55		3.40	6.75	5.50	2.13		6.75	1.75		2.03	6.75		6.75
San	Zam	Bis						7.65		4.20		4.25			6.38	2.50							2.58
San	Zam	Sur			1.75	1.75			6.75		3.35				4.25		3.40	13.50		4.25			1.68
San	Zam	San	8.75		5.00	2.50	11.00	3.35		4.25	0.90		4.25	5.50			0.85				4.25	11.00	

To	From	Via	43	44	45	46	47	48	49	50	51	52
Bis	Ceb	Bis							3.38		3.40	6.75
Bis	Ceb	Sur				6.75		6.75				
Bis	Ceb	San		6.75								
Bis	Zam	Bis			3.35	7.65	3.35	4.25	7.63		7.60	
Bis	Zam	Sur	3.38	11.90						3.40		
Bis	Zam	San	7.63				4.25			7.60		4.25
Sur	Ceb	Bis							3.38			5.50
Sur	Ceb	Sur				6.75	6.75	6.75	3.38	6.75	3.35	
Sur	Ceb	San	6.75		6.75							
Sur	Zam	Bis			1.23	0.90	3.35	0.88			7.60	
Sur	Zam	Sur	4.25	11.90		4.25				4.30		
Sur	Zam	San			2.13			7.63				5.50
San	Ceb	Bis									3.40	1.25
San	Ceb	Sur					6.75		3.38	6.75	3.35	

San	Ceb	San	6.75	6.75	6.75							
San	Zam	Bis			2.13	6.75		3.38	7.63			
San	Zam	Sur	0.88			4.25				0.90		
San	Zam	San	7.63		2.13		4.25	7.63		7.60		9.75

Bis = Bislig, Ceb = Cebu, Ili = Iligan, San = General Santos, Sur = Surigao, Tac = Tacloban, Tag = Tagbilaran, Zam = Zamboanga.

Source: Author.