Cost Benefit Analysis of Poroelastic Insulation Classes for Liquefied Natural Gas Plants

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Rationale

- Natural gas plants are massive and highly noisy places.
- Insulation is usually achieved through the application of poroelastic layers to the pipework and machinery.
- The plant operator gains two key benefits:
  - Process stability and efficiency through thermal insulation
  - Compliance with noise regulations for workers and at and beyond the plant boundaries.
- These benefits will outweigh the costs – typically around 0.5% of the total plant construction costs.

Wider benefits

- However, the operator does not consider the wider benefits of insulation in terms of reduced annoyance at residences
- Or indeed the economic benefit of protecting workers hearing
- Here we use LNG plants as an example to illustrate the potential societal benefits of poroelastic insulation.

Aim and definition

- To apply principles of cost benefit analysis to investments in poroelastic insulation to consider impacts on society as well as those to the individual firm.

- A cost benefit analysis seeks to include all the benefits and costs of a scheme to assess whether overall it is beneficial to society
- The method is usually applied to public sector investments, regulations and legislation.
- And may be used to rank projects or decide between alternative treatments

Structure

- Why is noise a problem?
- Analysis of predicted and measured noise around LNG plants
- Analysis of the engineering measures of the insulation performance
- Review of monetary values of noise nuisance
- Illustrative application of money values to the attained noise reduction.

Noise impacts on people

- annoyance
- hypertension,
- ischaemic heart disease
- sleep disturbance
- cognitive impairment in children
- productivity
- And at extremes hearing loss

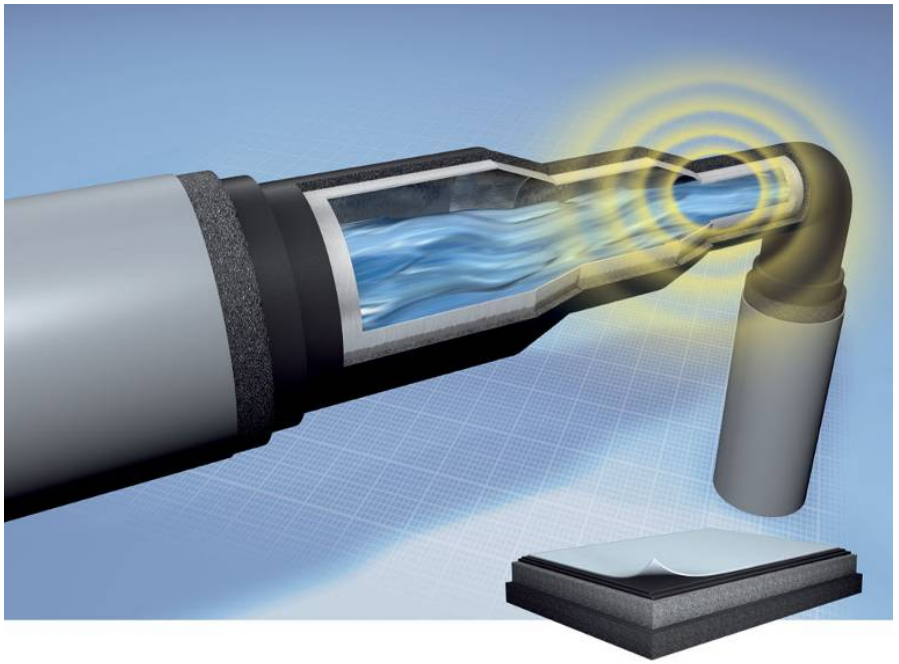
WHO burden of disease from environmental noise in Europe (2011)

WHO (1946) definition of health:
'A state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity'

Estimate years of healthy life lost per year in the EU and other Western European countries to be:

- 61,000 years for ischaemic heart disease,
- 45,000 years for cognitive impairment of children,
- 903,000 years for sleep disturbance,
- 22,000 years for tinnitus and
- 654,000 years for annoyance

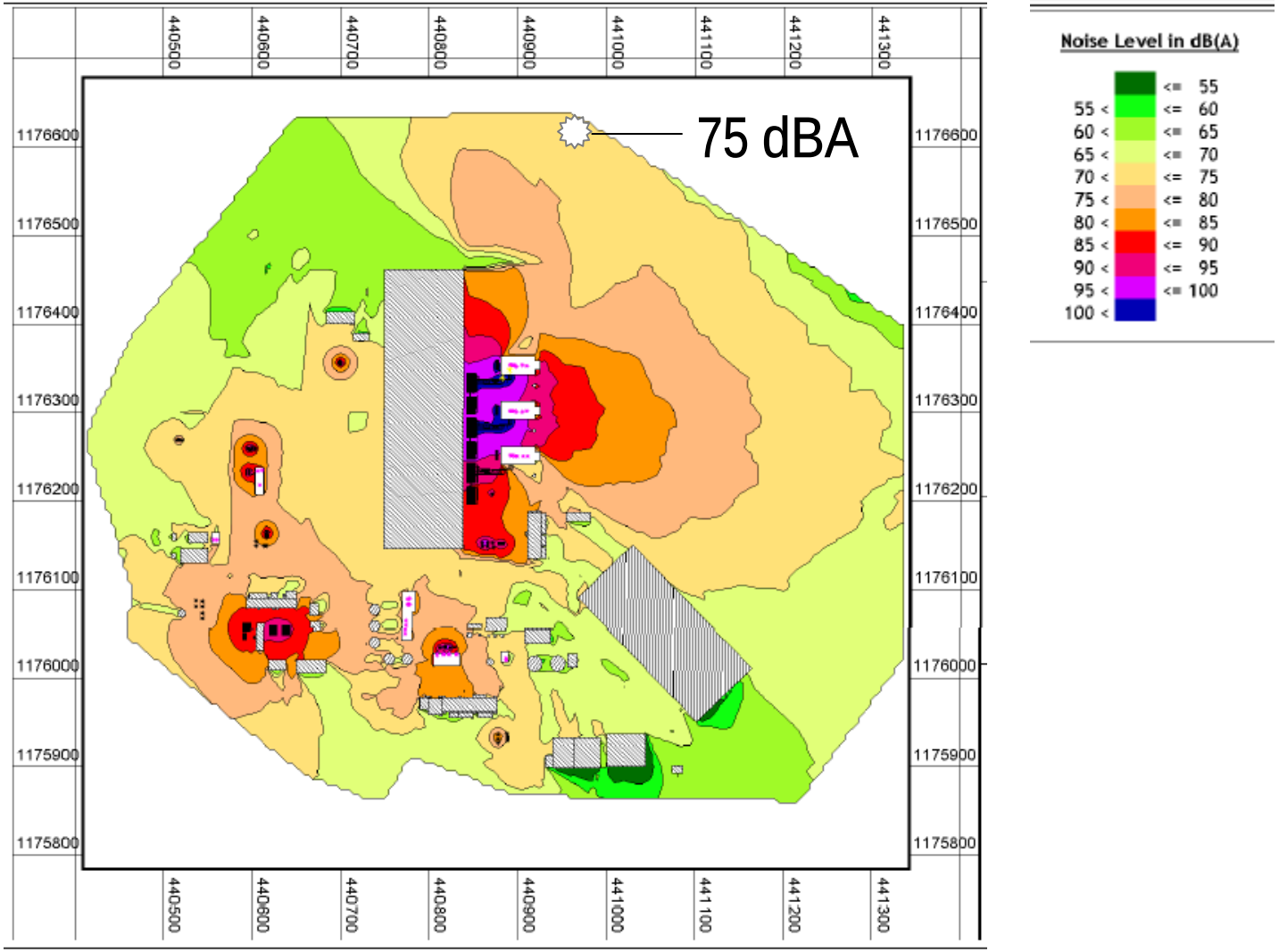
Problem



Typical Levels 110-120dB(A)!

Noise around LNG plant (untreated)

100 m



Poroelastic insulation is applied to reduce noise

ArmaSound Industrial *System A (EL)*

2	Arma-Chek R	2 mm
1	Armaflex	25 mm

Test Results Class A2	Octave band centre frequency, Hz						
nom. pipe-Ø: ≥ 300mm to < 650mm	125	250	500	1 000	2 000	4 000	8 000
Insertion loss, dB	1.4	- 3.7	3.9	12.8	18.9	28.6	38.9

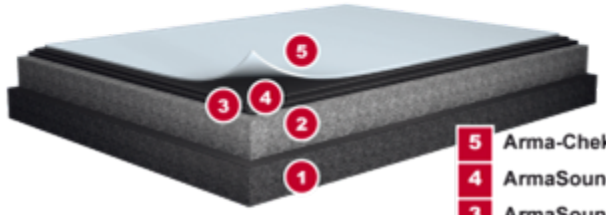
ArmaSound Industrial *System B (EL)*

3	Arma-Chek R	2 mm
2	ArmaSound RD 240	25 mm
1	Armaflex (1)	13 mm

Test Results Class B2	Octave band centre frequency, Hz						
nom. pipe-Ø: ≥ 300mm to < 650mm	125	250	500	1 000	2 000	4 000	8 000
Insertion loss, dB	0.9	0.8	9.2	17.2	28.6	38.2	42.0

(1) If thermal considerations for cold applications should be made: Class B will also be achieved with a 25mm layer of Armaflex in place of the 13mm layer.

ArmaSound Industrial *System C (EL)*



5	Arma-Chek R	2 mm
4	ArmaSound Barrier E	nom. 2 mm
3	ArmaSound Barrier E	nom. 3 mm
2	ArmaSound RD 240	25 mm
1	Armaflex	25 mm

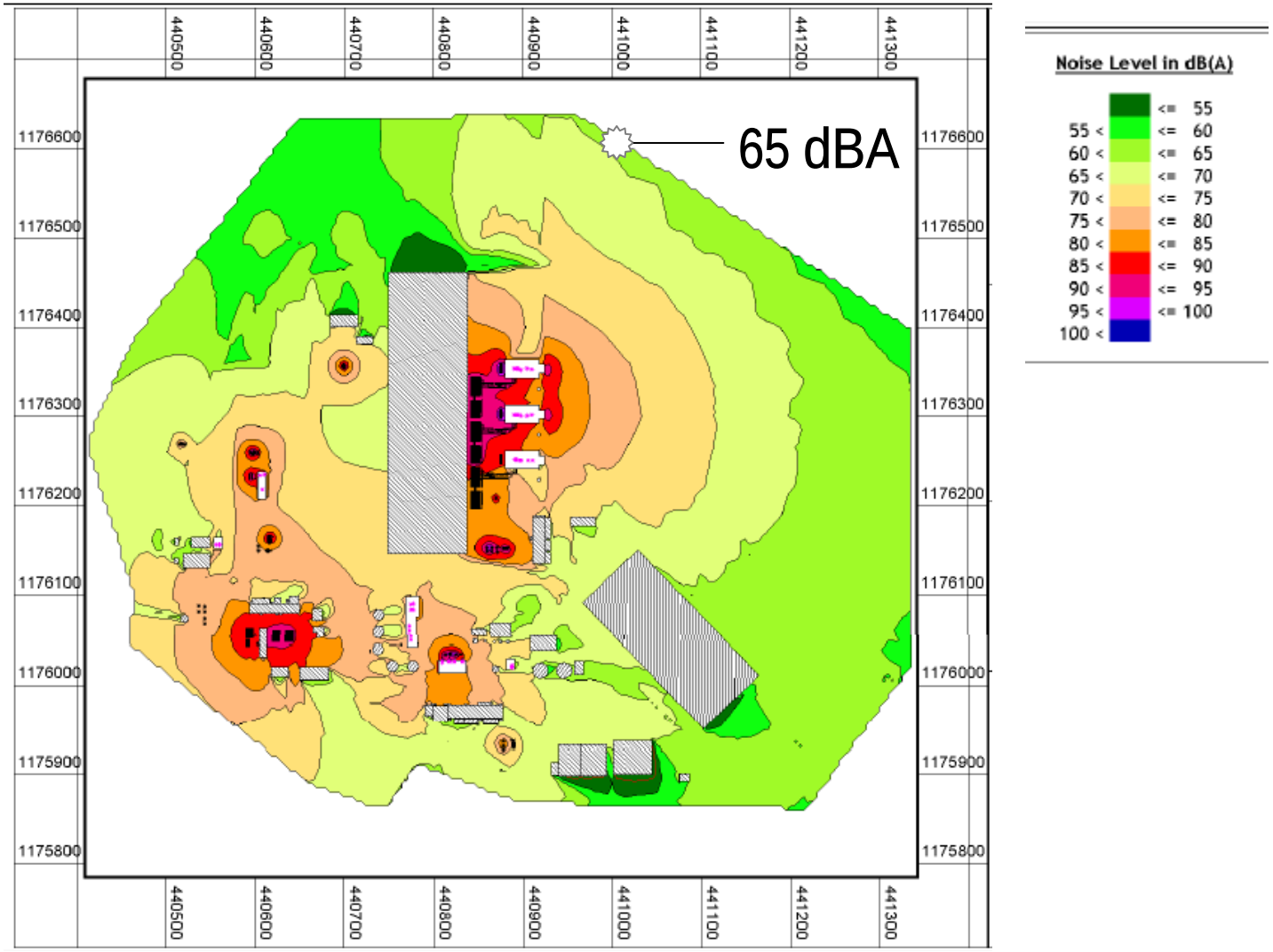
Test Results Class C2	Octave band centre frequency, Hz						
nom. pipe-Ø: ≥ 300mm to < 650mm	125	250	500	1 000	2 000	4 000	8 000
Insertion loss, dB	-1.2	11.8	16.3	24.3	36.0	49.8	47.6

ArmaSound Industrial *System D (EL)*

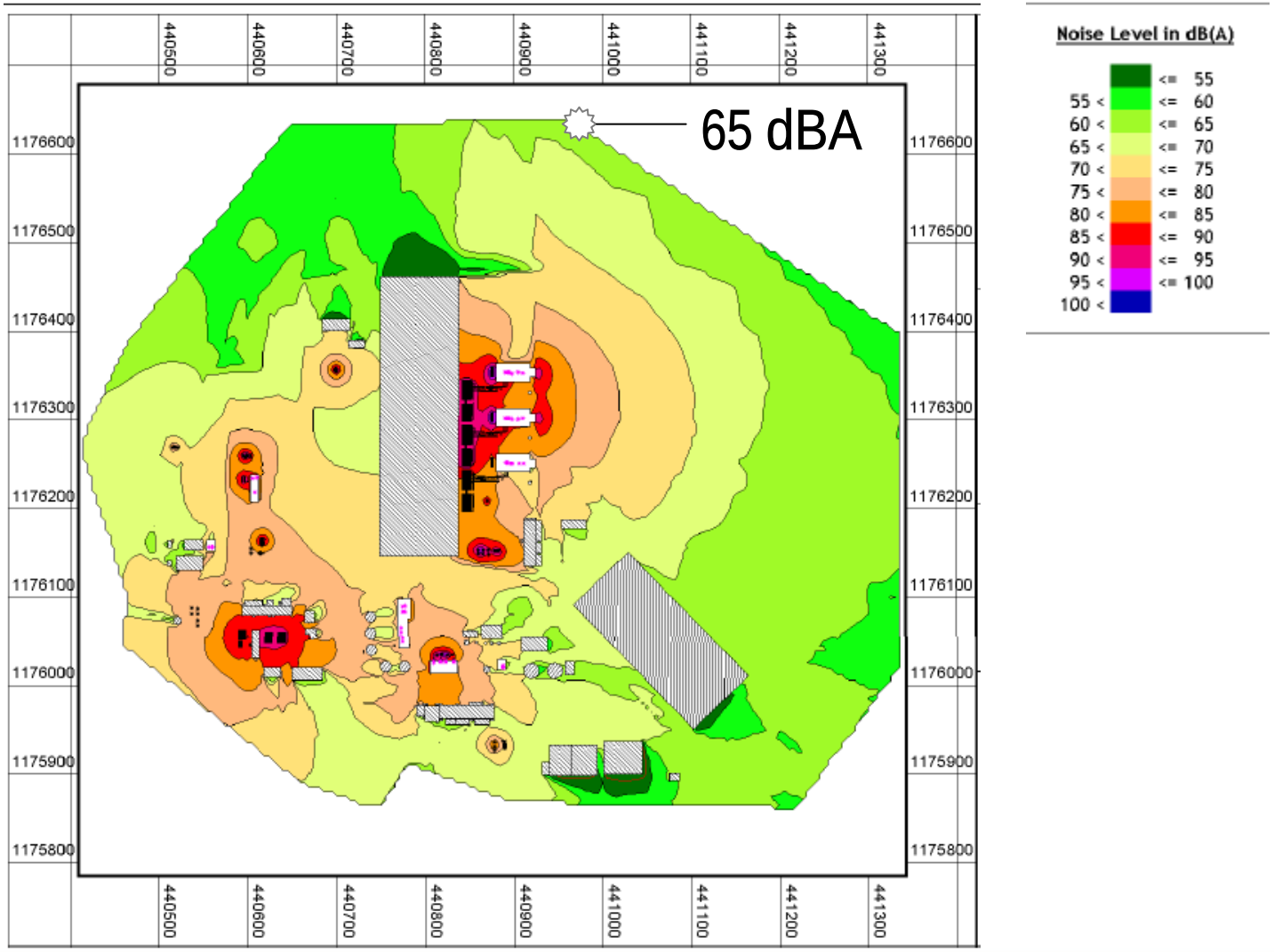
6	Arma-Chek R	2 mm
5	Armaflex	25 mm
4	ArmaSound Barrier E	nom. 4 mm
3	ArmaSound RD 240	25 mm
2	ArmaSound RD 240	25 mm
1	Armaflex	25 mm

Test Results Class D2	Octave band centre frequency, Hz						
nom. pipe-Ø: ≥ 300mm to < 650mm	125	250	500	1 000	2 000	4 000	8 000
Insertion loss, dB	-3.3	5.1	15.6	37.2	48.8	49.7	45.6

Noise around LNG plant (treated with Class A)



Noise around LNG plant (treated with Class B)



Poroelastic insulation costs and noise benefits

	IL, dB	Cost per metre with respect to Class A	Cost per dB with respect to Class A
Class A	20	1	1
Class B	25	1.5	1.2
Class C	36	2	1.1
Class D	46	3	1.3

Evidence on the costs of noise nuisance

Hedonic pricing:

- Air traffic noise – house prices fall by 0.45 and 0.64% per 1 dBA increase in noise levels (Wadud, 2013, meta-analysis of 53 values, range from 0% to 2.3%)
- Road traffic noise – average price fall 0.55% - range 0.08% to 2.22% (Bateman et al, 2001 review of 18 studies)

Stated preference:

- Surveys obtaining willingness to pay (WTP) or willingness to accept (WTA) changes in noise levels
- Contingent valuation or stated choice
- Navrud (2002) recommended a value in the range €2 to 32 per dB per household per annum based on 6 studies

Monetary value of noise

- Meta-analysis of stated preferences studies data covers:
  - 49 studies
  - 258 values
  - 23 countries
  - 40 years
- Regression analysis – dependent variable is value per dBA per household per annum in US$ 2009.

Regression Models: Influential variables

	Model I		Model II	
Variable	Coefficient (t stat)	Effect or elasticity	Coefficient (t stat)	Effect or elasticity
Constant	0.088 (0.29)		0.279 (0.064)	
Source: Road, rail, combined	Base		Base	
Air	0.969 (5.85)	+138%	0.841 (5.27)	+132%
Level: not available, 55-64dBA	Base		Base	
Less than 55dBA	-0.689 (2.75)	-50%	-0.465 (1.73)	-37%
Over 65dBA	0.644 (2.68)	+90%	0.567 (2.32)	+76%
Annoyed: not available; Slightly, Moderately, Very	Base		Base	
Not at all annoyed	-1.663 (7.73)	-81%	-1.627 (7.76)	-80%
Extremely annoyed	0.522 (2.43)	+68%	0.559 (2.67)	+75%
Log per capita GDP/1000	0.986 (10.93)	0.986	0.921 (6.78)	0.921

Regression model continued: design effects

Variable	Coefficient (t stat)	Effect or elasticity	Coefficient (t stat)	Effect or elasticity
Representation: % Change, Categorical, Verbal, Proxy, Simulation and Experienced change	Base		Base	
Decibel plus description	-1.913 (7.78)	-85%	-3.000 (7.70)	-86%
Annoyance	-1.620 (11.69)	-80%	-1.723 (9.64)	-82%
Consumer surplus measure:				
WTP for a gain	Base		Base	
WTP to avoid a loss	0.821 (2.88)	+127%	0.894 (2.94)	+145%
WTA to forgo a gain	1.143 (3.96)	+214%	1.286 (4.47)	+262%
WTA to compensate for a loss	1.816 (7.97)	+515%	1775 (7.82)	+490%
Combined in one model	1.710 (9.97)	+443%	1.752 (9.07)	+477%
Noise at home	Base		Base	
Noise during journey	1.667 (4.44)	+430%	1.580 (2.94)	+385%
Payment method: Weekly, monthly, annual, per journey	Base			
House price	1.79 (5.80)	+500%	1.62 (4.87)	+406%

Regression model continued: fixed effects

Variable	Coefficient (t stat)	Effect or elasticity	Coefficient (t stat)	Effect or elasticity
All other studies	Base		Base	
Study 2	2.080 (5.20)	+700%	1.844 (4.17)	+533%
Study 4	2.975 (5.82)	+1859%	2.834(5.25)	+1602%
Study 5	4.010 (6.94)	+5415%	3.881 (6.56)	+4747%
Study 6	1.420 (2.70)	+314%	n.s.	
Study 17	-2.952 (5.62)	-95%	-3.039 (5.63)	-95%
Study 18	-1.689 (3.22)	-82%	-1.744 (3.00)	-83%
Study 25	1.842 (3.38)	+531%	1.873 (2.93)	+551%
Study 30	-1.746 (4.04)	-83%	-1.61 (1.81)	-80%
Country specific				
All other countries	Base		Base	
UK	-0.353 (2.87)	-30%	n.s.	
Germany	-0.765 (4.50)	-53%	n.s.	
Italy	-0.846 (1.87)	-57%	n.s.	
Adjusted R^2 sample size	0.860 (257)		0.851 (257)	

Forecast values per household per annum per dB (2009 US$) (country GDP per capita in brackets)

	Hungary ($12,867)			UK ($35,164)			Denmark ($55,992)		
	<55dB	55-64dB	>65dB	<55dB	55-64dB	>65dB	<55dB	55-64dB	>65dB
Road WTPgain	6.81	13.56	25.81	18.34	36.53	69.56	29.02	57.79	110.04
Road WTAloss	41.84	83.34	158.68	112.75	224.57	427.60	178.37	355.26	676.45
Road WTPloss	15.47	30.81	58.67	41.69	83.03	158.09	65.95	131.35	250.10
Road WTAgain	21.35	42.52	80.96	57.52	114.57	218.15	91.00	181.25	345.11
Air WTPgain	16.23	32.33	61.55	43.74	87.11	165.87	69.19	137.81	262.40
Air WTAloss	99.77	198.72	378.38	268.86	535.49	1019.62	425.33	847.13	1613.01
Air WTPloss	36.89	73.47	139.90	99.40	197.98	376.98	157.25	313.20	596.37
Air WTAgain	50.90	101.38	193.04	137.16	273.19	520.18	216.99	432.19	822.92
Road WTPloss not at all annoyed	2.93	5.84	11.12	7.90	15.74	29.97	12.50	24.90	47.41
Road WTPloss extremely annoyed	26.07	51.93	98.88	70.26	139.94	266.45	111.15	221.37	421.52
Road WTPloss annoy (rep)	3.06	6.10	11.61	8.25	16.43	31.29	13.05	25.99	49.49
Road WTPloss Decibelplus	2.28	4.55	8.66	6.15	12.26	23.34	9.74	19.39	36.92
Road WTPloss Journey	81.93	163.19	310.72	220.78	439.74	837.30	349.27	695.66	1324.59

Comparison of WebTAG and model estimate values for road traffic noise per dBA per household per annum at UK £ 2010

Noise level	WebTAG	Geometric Mean CL and CG	Geometric Mean EL and EG
<55dB	24.67	30.94	33.32
55 to 64dB	58.82	61.62	66.06
>65dB	93.09	117.34	126.35

So

- If we assume an LNG plant in the UK
- With boundary noise of 75dB (unshielded) and a relatively urbanised port location:
  - 100 households within a 70-75 dB band
  - 200 households within a 65-70 dB band
  - 300 households within a 60-65 dB band
  - 400 households within a 55-60 dB band
- With class A insulation and fairly conservative assumptions this might change to: zero, 200, 300, 300, and 200 now below 55 dB
- Valuing the changes, using 55dB as the threshold gives an annual benefit of £212,805
- Assuming a change of 10 dB per household would increase this benefit to about £500,000

If we assume a more rural area

- Lower background noise, so a threshold of 40dB
- Say 19 properties affected
- Annual benefits around £10,000

Conclusions

- Looked at the noise insulation benefits of porous materials at LNG plants
- Considered the economic costs of noise nuisance
- Provided illustrative examples of the social benefits of insulation.
- Can use the same techniques to examine social benefits of any other poroelastic insulation and costs across a range of noise control interventions – do the benefits exceed the costs?
- Approach may also be used to assess the costs of compliance with regulation.