Undergrounding HV and EHV – Window of Opportunity Opens

Report
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Gorham & Partners
MANAGEMENT CONSULTANTS

I.C.F.
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CABLEMAKERS
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Executive summary

- Most Transmission System Operators (TSOs) have a history of only considering cable as a solution of last resort
- TSOs have entrenched views on the costs of cable vs. line, and tend to look primarily at installed costs rather than lifetime costs
- Recent evidence suggests that cable can be economically lower cost at 110kV, but this finding has not been communicated by any authority the TSOs would take notice of

Executive summary (cont.)

- No TSO will therefore willingly underground at HV or EHV levels unless:
  - They accept the additional installation cost for broader business reasons, OR
  - An agreement with government/municipal authority is put in place with additional funding made available to the TSO
- Bringing about a policy change will require some or all of the following factors to be present
  - Installation cost ratio below 2
  - Availability of and debate on up-to-date cost comparisons
  - Agreement between stakeholder groups to underground
  - Funding mechanism to bridge the gap
- The ICF can influence these factors

Objectives and methodology

This presentation aims to update and build on the study carried out by Gorham & Partners in 1994, with a focus on >50kV levels

- Have cost ratios at HV and EHV improved in cable's favour?
- If the cost ratios have improved, is this reflected in an improved share for cable of annual circuit kms installed in the HV/EHV network?
- Are there other factors that influence TSOs in choosing cable over line?
- Can the cablemakers influence this decision?

Gorham & Partners have gathered data on circuit lengths from 1993 to the present at HV and EHV (>50kV)

Country data sources

Europe

- Austria – VEOE
- Belgium – ELIA
- Denmark – Dansk Energi
- Finland – Sener
- France – RTE/CIREF
- Germany – VDEW
- Greece – DESME
- Italy – GRTN
- Netherlands – Nuon / EnergieNed
- Norway – Statnett / Statistics Norway
- Portugal – EDP
- Spain – UNESA
- Sweden – STEM
- Switzerland – BKW (FMB)
- United Kingdom – National Grid Transco

North America

- Canada – Canadian Electricity Association
- USA – Edison Electrical Institute

Asia

- China – Beijing Electric, Shanghai Electric
- Hong Kong – Hong Kong Electric
- Japan – J Power
- Malaysia – Tenaga Nasional Berhad
- Singapore – Power Grid
- South Korea – KEPCO
- Thailand - EGAT

This data has been supplemented with a series of interviews to explore TSO experience and policies, and cost comparisons between line and cable

Interviews conducted

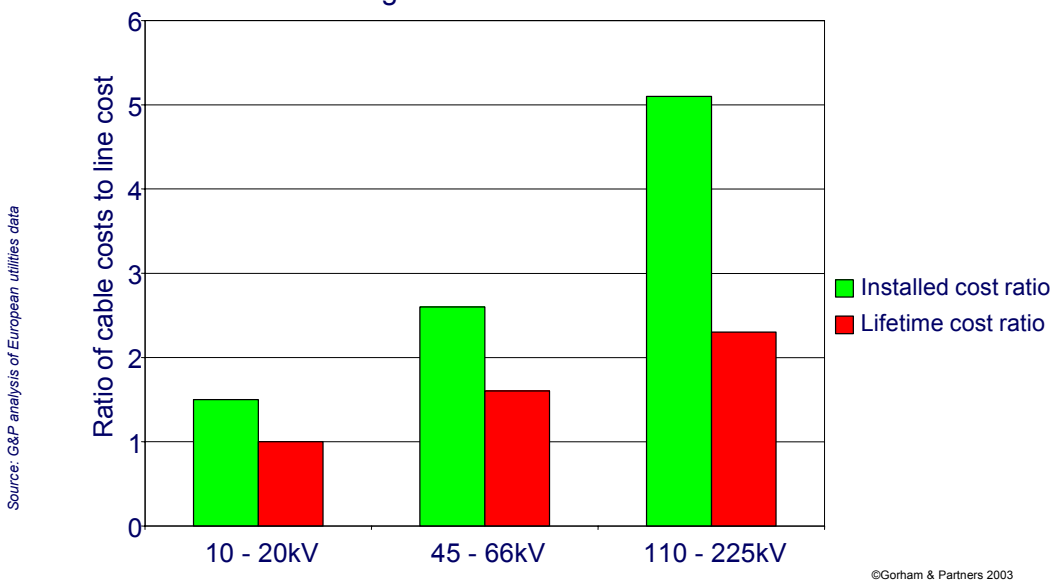
Europe
- Iberdrola
- Nesa
- Nuon
- RED
- RTE
- Svensk Energi
- Svenska Kraftnät
- Technische Universität Graz
- Vattenfall

North America
- BC Hydro
- Consolidated Edison New York
- Entergy
- Hydro Quebec
- Long Island Power Authority
- Southern California Edison

Asia
- Beijing Electric
- Hong Kong Power
- JPS Cable, Japan
- KEPCO, South Korea
- Power Grid, Singapore
- Shanghai Electric
- Tenga Nasional Berhad, Malaysia

Improvements in cost ratios

In 1994, Gorham & Partners obtained 13 studies examining the cost ratios between overhead and underground circuits



Source: G&P analysis of European utilities data

This study found that cost parity was achievable between cable and line at <20kV and below

- Based on lifetime costs, undergrounding was economically attractive at 20kV and below (i.e. a cost ratio of 1 or less), but swiftly became uncompetitive as kV levels increased

- Installed costs for cable are typically higher than for line
  - Cable is more expensive than line
  - Tunnels, trenching or ducting vs. pylons
  - Splices and terminations

- Operating costs and loss costs for cable are typically lower than for line
  - Cable is less affected by the weather
  - Breaks in cable are less frequent (but take longer to repair)
  - Larger conductor cross-section leads to reduced heat transfer and losses

Obtaining comparative cost studies in 2003 has been more difficult

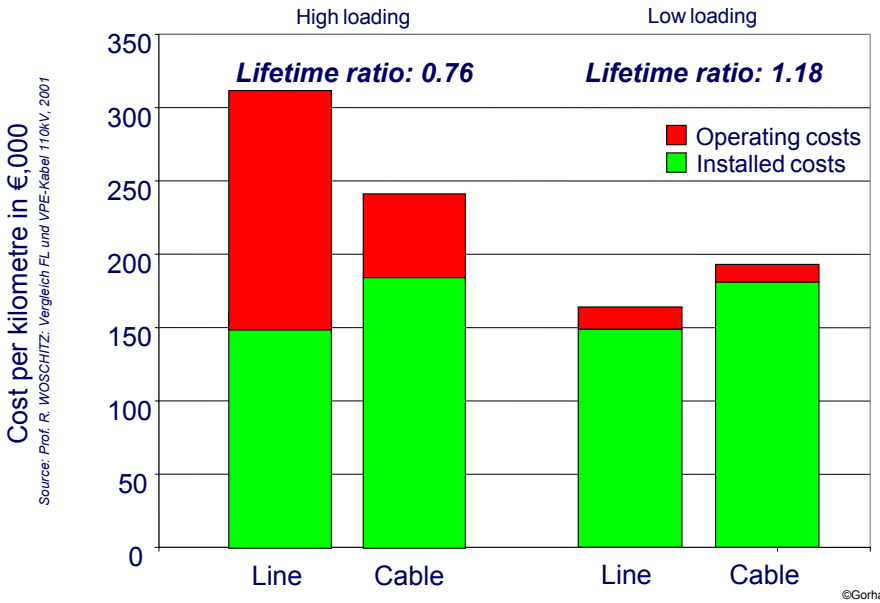
- Three types of cost data have been obtained:
  - Current cost studies where the ratios are calculated from actual costs
  - Cost ratios provided by TSOs in conversation or from their own publicity documents, where no detailed numbers have been made available to support the ratios
  - Reports published by other organisations post 1994

- The majority of the cost studies have originated from Europe (similar to the experience in 1994)

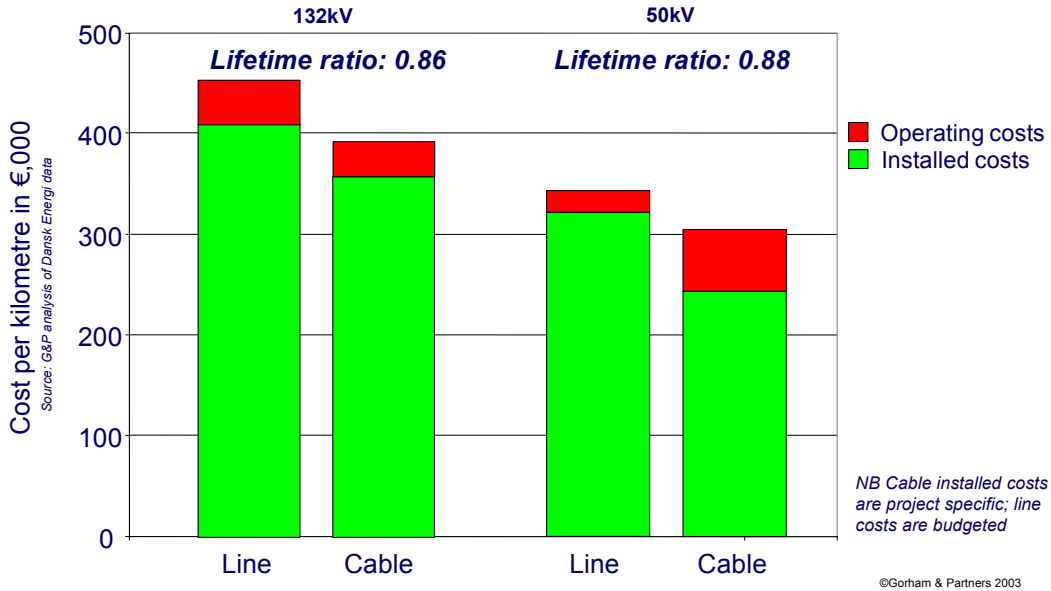
- We believe that the relative difficulty in obtaining these cost ratios has two root causes:
  - Break-up of national monopolies leading to fragmentation of information
  - Lack of TSO belief that cable is a realistic alternative for line at >50kV, leading to no TSO conducting a comparative study into lifetime costs of cable and line

- Detailed findings are presented in Appendix 1

Analysis of Austrian projects shows that cost parity is achievable at 110kV



Denmark projects have exceeded parity for cable at 132kV and 50kV



Recent technical reports show that the relative cost of installing cable can vary significantly

Year	Report author and title	Approach	Key finding
2003	ETSO: Position on the use of underground cables to develop European 400kV networks	Paper setting out perceived disadvantages of cable vs. overhead	• Differential installation cost between underground and overhead is 10 to 12 times per km
2002	ICF Consulting: Unit costs of constructing new transmission assets at 380kV within the EU, Norway and Switzerland	Country cost analysis of overhead installation costs	• Installation costs can vary from €200,000/km to €800,000/km for line (the report focuses on line)
2001	Christian KERN: Rapport sur l'apport de nouvelles technologies dans l'enfouissement des lignes électriques à haute et très haute tension	Review of global approaches to undergrounding transmission circuits	• Political will is required for large undergrounding projects • Large projects will reduce overall costs of undergrounding
1996	CIGRE: Comparison of high voltage overhead lines and underground cables	Based on a survey of TSOs, concluding that the cost ratio of installing cable is between 3.4 and 33.3 times overhead	• Installation cost ratio of cable is 3.4 – 33.3 times overhead

Source: G&P analysis

The cost-competitiveness of cable is strongly dependent on the relative cost of installation

One TSO we spoke to reduced the installed costs of 120kV transmission cable by 27% on urban projects

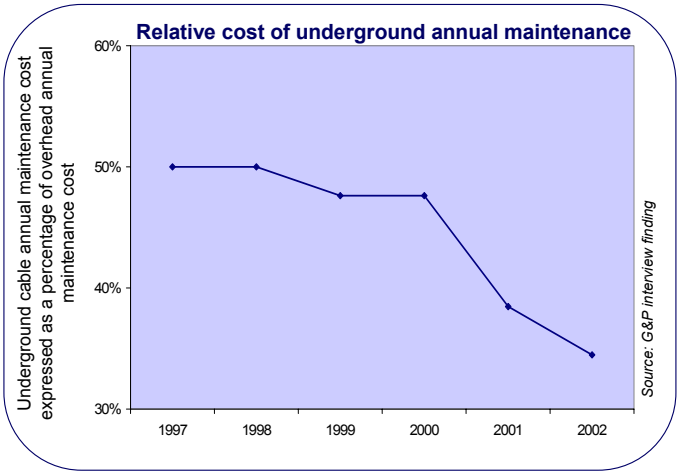
€1,170,000/km

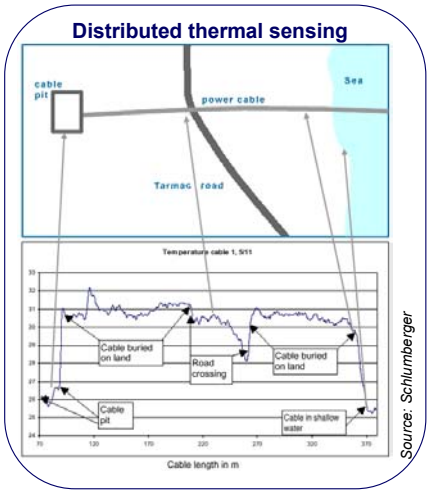
- Partnering with a cable manufacturer to:
  - Reduce the thickness of the XLPE insulation
  - Increase the length of cable in a single run to 800m
- Redesigning and pre-fabricating joint bays
- Shortening overall project time through carrying out civil work whilst the cable was being manufactured
  - Reduced interest payments on project
  - Reducing cost of project management

€860,000/km

There is limited awareness across the TSOs we interviewed of international best practice

Another TSO has introduced distributed thermal sensing as part of efforts to reduce annual maintenance costs of cable





In 1994, cost parity was reached around 20kV: now parity is achievable around 110kV

- Cost of cable has reduced by 20 – 25% over the past decade
- Civil work is more expensive for cable but its cost can be reduced
- 2nd generation cables are reducing maintenance issues seen in 1st generation

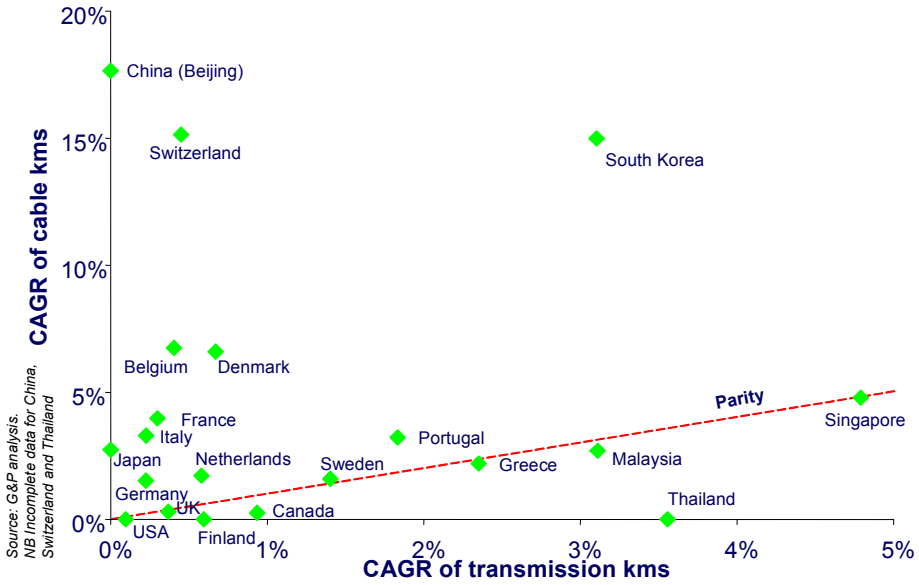
Have cable circuit lengths increased over the last decade?

Underground transmission circuit lengths

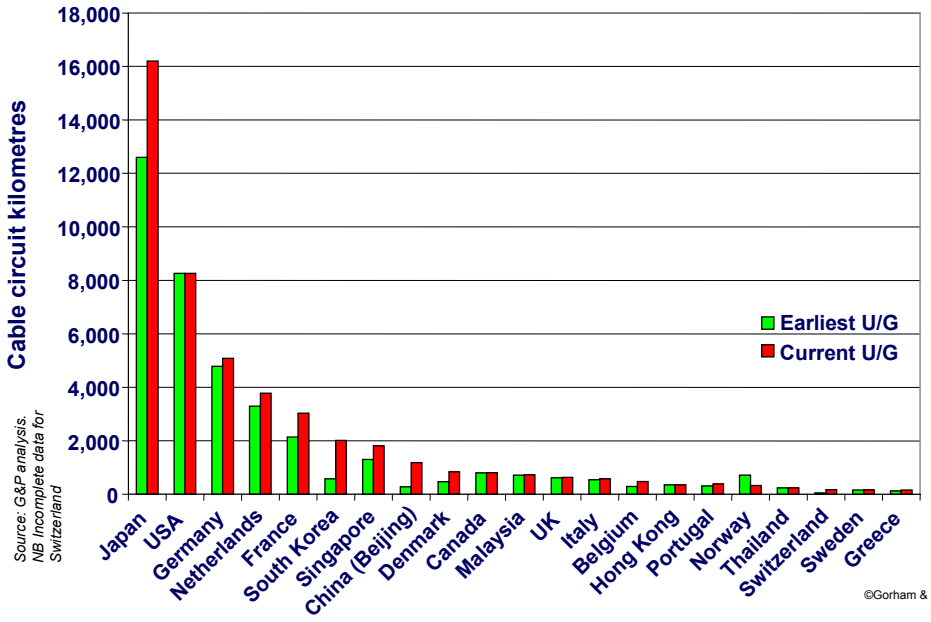
A reduction in relative cable cost should result in an increase in circuit lengths

- If cost is the primary factor influencing cable usage, a reduction should lead to greater installation of transmission cable over time
- Cost parity was achieved at c. 20kV in the early '90s
- Cost parity is achievable at c. 110kV today
- Investigation into network circuit lengths do show an increase in cable usage at >50kV
- In the countries examined, cable circuit length at >50kV has increased from 38,500 kms (earliest available data) to 47,000kms (most recent data)

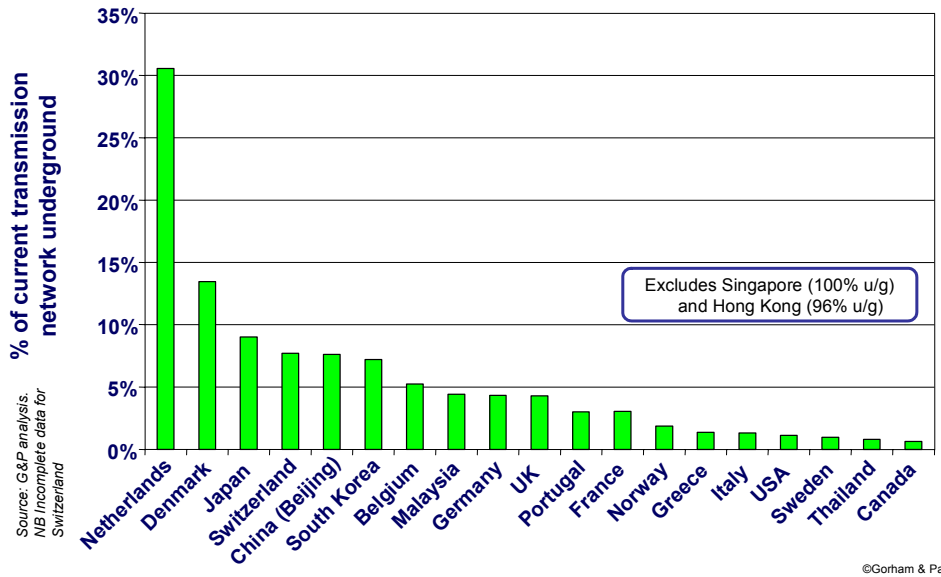
Cable circuit kilometres have grown at a faster annual rate than the overall transmission network



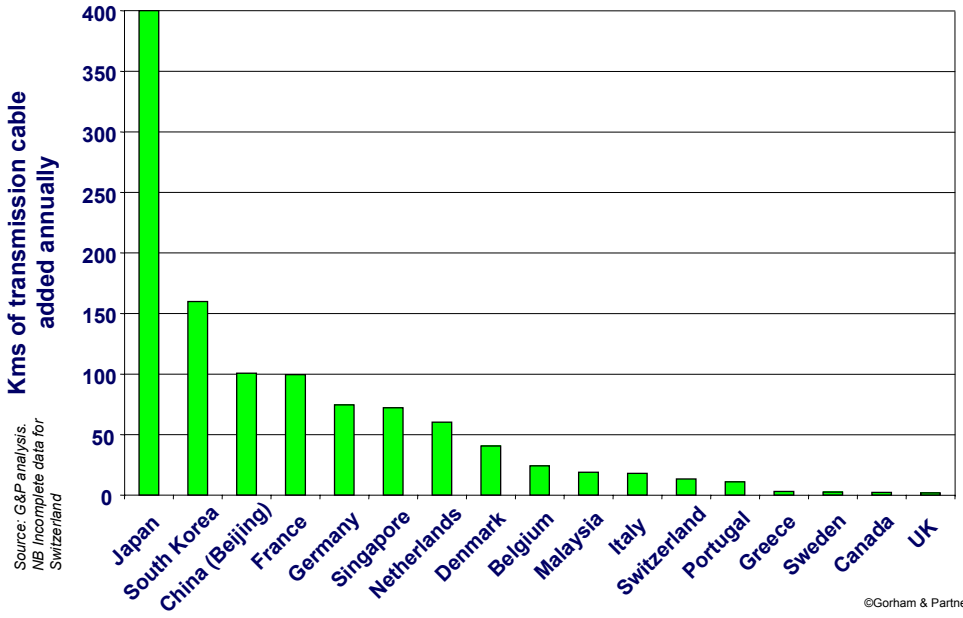
The increase in cable circuit kilometres has differed by country



Cable still has only a small share of total transmission network length

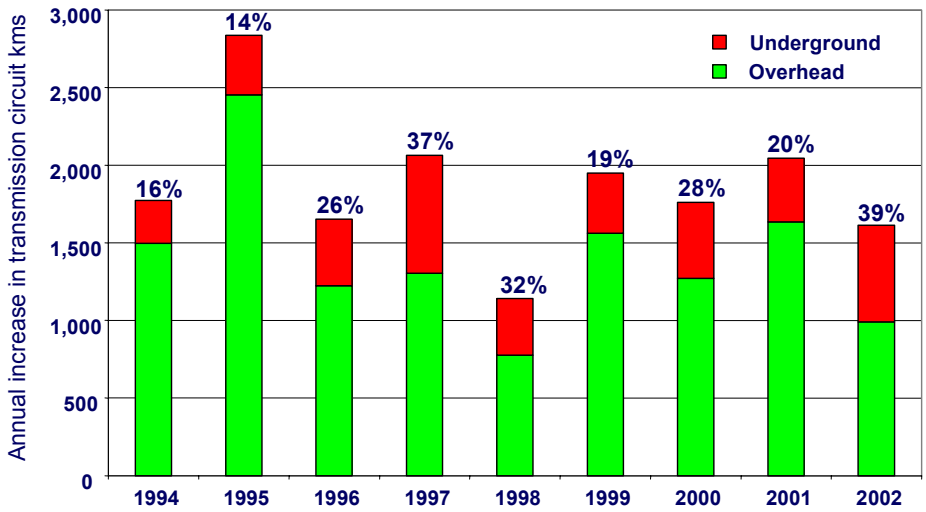


The majority of countries add fewer than 100kms of cable per year



Source: G&P analysis. NB Incomplete data for Switzerland

Cable as a proportion of all newly installed transmission lines shows a general upward trend from the early 90's



NB Analysis performed on data from 12 countries. Figures show % cable.

More cable is now being used at transmission voltages, but the picture is not consistent

- HV cable networks are growing much faster than overall HV networks
- HV cable is taking market share from line
- More HV cable is being installed annually now than in 1994, but still in low volumes
- Cable penetration varies by country

Are there significant factors other than cost that drive the usage of cable?

TSO attitudes towards cable

Our interviews have revealed that external pressure causes gradual changes in TSO policy

- The majority of TSOs interviewed have a culture and history of installing overhead lines
  - Tried and tested technology
  - Long asset lifetimes leads to slow pace of innovation
  - XLPE seen as a recent innovation
- Changes in policy come about through external pressures
- Typical triggers for a switch in TSO policy appear to be:
  - Major climatic event leading to review of grid resilience
  - Adoption of new consultation processes giving a wider community of stakeholders the right to put their views forward and challenge TSOs
  - Change in governmental policy, leading to regional or national agreements (voluntary or otherwise) to increase levels of undergrounding

Government policies are effective at influencing the installation of cable

Region	Regional approach	% of transmission circuits (>50kV) underground	Underground circuit kms
Asia	• Government at national and local levels often mandates underground installation, but does not always construct a viable funding approach • Visual benefits of undergrounding seen as important	**9%**	**22,500**
Europe	• Differs by country • Some agreements exist between TSOs and regulators for undergrounding targets and cost recovery from consumers • Visual and environmental benefits of undergrounding seen as important	**4%**	**15,500**
North America	• No apparent consistent national approach • TSO policy driven by "least cost" approach • Overhead culture dominant • Limited consumer pressure for underground	**1%**	**9,000**

Source: G&P analysis, interview findings

Asian countries have strong government support for cable, but additional funding mechanisms are not always provided

Country	National policy	TSO policy	Funding structure
China - Beijing	• Beijing regional government regulations call for all overhead line to be undergrounded in the Beijing urban area	• Overhead preferred as seen as lower cost • Lack of funding has inhibited undergrounding (<200kms of mainly 10kV line in 5 years)	• Funding structures have not been set up to cover the cost of undergrounding existing overhead lines • "Local government issues policy, but leaves the TSO to find means to raise funds"
Singapore	• For space reasons, the government decided in 1959 that 100% of the network should be underground • Underground seen to have aesthetic benefits	• New and replacement build is underground • Entrenched cable is being replaced with tunnels, to extend asset life to "100 years"	• Electricity prices paid for by consumer cover the cost of underground structures
South Korea	• Urban residents have concerns about overhead lines: perceived health risk; obstruction of view; drop in real estate prices	• Overhead lines are being replaced by cable as residents demand their removal and urban areas expand	• TSO is partially state-owned: funding comes through a combination of consumer prices and tax allocation

Source: Interview findings

European countries are putting pressure on TSOs to take consensus-driven decisions

Country	National policy	TSO policy	Funding structure
France	• Regional authorities work with RTE to strike a balance between the need to develop the network and the local preoccupations for the environment.	• RTE have made a commitment not to increase the total length of the national overhead transmission network	• Local region contributes up to 1% in co-financing • Little attempt has been made to investigate the willingness of consumers to pay for the cost differential
Netherlands	• At 50kV and above, only underground is allowed	• Under pressure from cities to remove existing overhead	• TSO seeks funding or other quid pro quos from the cities to recoup the additional cost of underground
Sweden	• 1998 environmental legislation requires TSO to reapply for all rights of way on expiry, through a comprehensive consultation process involving local residents	• Starting to accept that they can no longer operate an "overhead only" policy • Cable being considered more favourably	• Regulator can impose a decision on with no right of appeal: TSO has to bear all costs

Source: Interview findings

North American TSOs have adopted a "least cost" approach

Country	National policy	TSO policy	Funding structure
Canada	• No overall national policy • Individual cities (e.g. Vancouver, Victoria) have banned overhead at transmission levels for predominantly aesthetic reasons • In some provinces, TSOs choose not to install transmission lines in cities	• "Officially overhead unless someone else will pay" • Aim to reroute overhead rather than build underground	• TSO is given no assistance at transmission levels, but at distribution levels the costs are evenly split between TSO, provincial government and the affected community
USA	• Federal regulator focuses on supply reliability • Different legislative approaches taken by states and cities (line is sometimes forbidden for space reasons, e.g. in NYC) • Strong line culture amongst TSOs	• "Underground is the last viable alternative if there are no other options" • Aim to reroute overhead rather than build underground • Underground typically used to pass obstacles (e.g. rivers, railways, airports)	• Consumers can request underground, but TSOs will seek to pass on the additional costs direct to the consumers as a one-off charge • Funding mechanisms do not appear widespread but do exist (California's Rule 20A allows TSOs to recoup the additional costs from consumers via future electricity rates)

Source: Interview findings

New stakeholders are becoming more important to network decisions

Past – "Imposition"	Present – "Consultation"
State-owned monopoly (generator and supplier)	Super-national government National government Regulator Pressure groups TSO Regional government Local communities Individual residents

Cost remains an important factor, but the trend in Asia and Europe is for new stakeholders to consider other factors too

External events draw attention to transmission network performance

New York City, 2003

Quebec province, 1998

And London, Copenhagen, Rome…

TSO policy is moving from its historic position to one more favourable to cable at >50kV

Past

- Unwilling to pay incremental costs for cable
- Overhead line seen as the default solution
- Cable seen as expensive solution

Present

- Cost sharing with other stakeholders
- Growing awareness that cable has benefits
- Cable seen increasingly as expedient solution

External pressure from governments and consumers is bringing about a gradual change in TSO attitude

Implications for ICF

TSOs are starting to change their policies

- Most TSOs in Europe and North America are culturally pro-overhead
- Marginal voluntary TSO policy changes on HV/EHV network since 1994
- No internal motivation to study or monitor cost ratios
- Cable is generally not even considered unless TSO is forced to do so
- TSO perceptions of current cost ratios are anecdotal and lag real position
- Three factors only appear to have any impact on TSO network policy:
  - Power of the state (laws or regulation)
  - Power of the elements (major outages)
  - Financial logic of cost comparisons
- Gradual shift in Europe and some parts of the US to consult householders on line routing is starting to force TSOs to gradually change policy
- Ultimate ingredient for change appears to be the voluntary (or legislated) agreement with government
- TSO willingness to meet an installation cost difference if other benefits accrue

A number of factors are aligning in favour of re-energising cable

- Recent extreme events have increased attention on network resilience
- Cost ratios are moving in the right direction, but many TSOs seem unaware of them
- Efforts by pro-cable TSOs are bringing installation costs down more
- Cables being seen as the technology of the future (environmental benefits, superconductors)
- Mandatory consultation processes are an increasing trend
- New non-technical senior executives running newly deregulated TSOs

The time is right for a proactive ICF programme

- No credible body is making the case for cable
- “The cablemakers are too passive” – European TSO interviewee
- Non-TSO stakeholders would welcome the availability of facts on costs
- Competitive position of cable would be substantially improved
- Revenue of ICF members could be improved
- Experience of market development programmes in other sectors (copper, aluminium) is positive
- ICA participation is available

Appendices

Cost studies – explanatory notes

- Data on actual projects has been received from Austria, Denmark and the Netherlands where the TSOs were in a position to compare line costs with cable
- TSOs in Spain and Sweden have also provided data on costs which have not been included in this appendix
  - Unable to obtain sufficiently complete data from Spain within the project timeframe
  - Data from the Swedish TSO (line only) was obtained for 220kV installed and lifetime costs, but no equivalent cable cost data was available
- In the majority of cases, the comparison between the relative cost of line and cable involved the use of budgeted figures
- From a standard template, Gorham & Partners has calculated the installed cost ratio and lifetime cost ratio
- Lifetime cost ratio calculations have required assumptions to be made on the financial cost of losses (see next page for detail)

Lifetime cost ratios have a low sensitivity to assumptions about cost of losses

- As calculating the cost of future losses involves a number of key variables (e.g. electricity price, average line loading, conductor cross-section), a sensitivity analysis was performed on the Denmark and Netherlands data
- Cost of loss assumptions are based on actual data received for comparable cable types. Key variables in our model are:
  - Overhead cost of losses
  - Relative cost of losses for cable as a percentage of the cost of losses for line
- Denmark
  - A 50% change in the cost of losses results in a 3 – 6% change in the lifetime cost ratio
  - A 66% change in the differential results in a 2% change in the lifetime cost ratio
- Netherlands
  - A 50% change in the cost of losses results in a 7 – 10% change in the lifetime cost ratio
  - A 66% change in the differential results in a 2% change in the lifetime cost ratio

Austria cost studies

Euros / km		**Austria 110kV** Euros / km	**Austria 110kV** Euros / km	**Austria 110kV** Euros / km
MVA		N/a	N/a	N/a
Specification	O/H	FeAl240/40	FeAl240/40	FeAl 240/40
	U/G	VPE 64/110kV	VPE 64/110kV	VPE 64/110kVCu 500RM/35 1 System
Conductor / Cable Cost	O/H	44,040	44,040	24,927
	U/G	78,487	78,487	79,286
Other Material Costs	O/H	67,150	67,150	41,714
	U/G	8,357	8,357	7,558
Installation / Engineering	O/H	37,427	37,427	43,168
	U/G	94,184	94,184	191,202
Wayleave	O/H			
	U/G			
Total	**O/H**	**148,616**	**148,616**	**109,809**
	U/G	**181,028**	**181,028**	**278,046**
Installation Cost Ratio		**1.22**	**1.22**	**2.53**
Losses	O/H	9,268	77	9,229
	U/G	2,804	24	2,762
Maintenance / Repair	O/H	872	872	872
	U/G	727	727	727
Life In Years		30	30	30
Net Interest Rate		4.5%	4.5%	4.5%
Cost Adjustment Factor		16.29	16.29	16.29
Total Operating Costs	**O/H**	**165,182**	**15,460**	**164,554**
over 30 years	**U/G**	**57,516**	**12,229**	**56,824**
Total Lifetime Cost	**O/H**	**313,798**	**164,077**	**274,362**
	U/G	**238,544**	**193,257**	**334,871**
Lifetime Cost Ratio		**0.76**	**1.18**	**1.22**
Notes		Utilisation of 5000 hours	Utilisation of 1000 hours	Utilisation of 5000 hours

Source: Technische Universität Graz

Denmark cost studies

Euros / km		**Denmark 132kV** Euros / km	**Denmark 132kV** Euros / km	**Denmark 132kV** Euros / km	**Denmark 50kV** Euros/km	**Denmark 50kV** Euros/km	**Denmark 50kV** Euros/km
Terrain							
MVA		225	180	180	60	50	50
Specification	O/H	Budget Figures	Budget Figures	Budget Figures	G&P assumption	G&P assumption	G&P assumption
	U/G	2000 mm2 Al XLPE	1600 mm2 Al XLPE	300 mm2 Al XLPE	800mm2 Al XLPE	500mm2 Al XLPE	500mm2 Al XLPE
Conductor / Cable Cost	O/H						
	U/G	206,076	242,442	242,442	94,000	109,000	114,450
Other Material Costs	O/H						
	U/G						
Installation / Engineering	O/H						
	U/G	546,841	126,070	126,070	161,580	180,430	289,490
Wayleave	O/H						
	U/G						
Total	**O/H**	**404,070**	**404,070**	**404,070**	***323,256***	***323,256***	***323,256***
	U/G	**752,917**	**368,512**	**368,512**	**255,580**	**289,430**	**403,940**
Installation Cost Ratio		**1.86**	**0.91**	**0.91**	**0.79**	**0.90**	**1.25**
Losses	O/H	*4,600*	*2,944*	*2,944*	*322*	*230*	*230*
	U/G	*1,380*	*883*	*883*	*97*	*69*	*69*
Maintenance / Repair	O/H	431	431	431	1,210	1,210	1,210
	U/G	673	673	673	3,000	3,000	3,000
Life In Years		30	30	30	30	30	30
Net Interest Rate		4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
Cost Adjustment Factor		16.29	16.29	16.29	16.29	16.29	16.29
Total Operating Costs	**O/H**	**81,955**	**54,979**	**54,979**	**24,956**	**23,458**	**23,458**
over 30 years	**U/G**	**33,451**	**25,358**	**25,358**	**50,444**	**49,994**	**49,994**
Total Lifetime Cost	**O/H**	**486,025**	**459,049**	**459,049**	**348,212**	**346,714**	**346,714**
	U/G	**786,367**	**393,869**	**393,869**	**306,024**	**339,424**	**453,934**
Lifetime Cost Ratio		**1.62**	**0.86**	**0.86**	**0.88**	**0.98**	**1.31**

Numbers in italics are G&P assumptions based on alternative data sources

Source: Nesa, G&P analysis

Netherlands cost studies

Euros / km	I	**Netherlands 150kV**	**Netherlands 150kV**	**Netherlands 50kV**	**Netherlands 50kV**
		Euro / km	Euro / km	Euro / km	Euro / km
Terrain		Rural	Urban	Rural	Urban
MVA		n/a	n/a	n/a	n/a
Specification	O/H	Budget figures	Budget figures	Budget figures	Budget figures
	U/G	1200Al, 3 ph, XLPE	1200Al, 3 ph, XLPE	400Al, 3ph, XLPE	400Al, 3ph, XLPE
Conductor / Cable Cost	O/H				
	U/G	180,000		45,000	
Other Material Costs	O/H				
	U/G	40,000		5,000	
Installation / Engineering	O/H				
	U/G	330,000		120,000	
Wayleave	O/H				
	U/G	50,000		30,000	
Total	**O/H**	**250,000**	**250,000**	**100,000**	**100,000**
	U/G	**600,000**	**700,000**	**200,000**	**250,000**
Installation Cost Ratio		**2.40**	**2.80**	**2.00**	**2.50**
Losses	O/H	*4,600*	*4,600*	*230*	*230*
	U/G	*1,380*	*1,380*	*69*	*69*
Maintenance / Repair	O/H	3,023	3,023	884	884
	U/G	1,641	1,641	890	890
Life In Years		30	30	30	30
Net Interest Rate		4.5%	4.5%	4.5%	4.5%
Cost Adjustment Factor		16.29	16.29	16.29	16.29
Total Operating Costs over 30 years	**O/H**	**124,179**	**124,179**	**18,147**	**18,147**
	U/G	**49,212**	**49,212**	**15,622**	**15,622**
Total Lifetime Cost	**O/H**	**374,179**	**374,179**	**118,147**	**118,147**
	U/G	**649,212**	**749,212**	**215,622**	**265,622**
Lifetime Cost Ratio		**1.74**	**2.00**	**1.83**	**2.25**

Numbers in italics are G&P assumptions based on alternative data sources *Source: Nuon, G&P analysis*

Network length data for >=50kV has been collected for 24 countries

- The move to the deregulated environment has had considerable impact on the availability of network length data
  - Availability
  - Completeness of coverage
  - Consistency from year-to-year
  - Historical continuity
- As a result, some data (in italics, shaded in blue) has been excluded from calculations

Austria

	1993	1994	1995	1996	1997	1998	1999	2000
Total circuit length	**9,477**	**9,437**	**9,434**	**9,445**	**9,429**	**9,452**	**9,564**	**9,568**
110kV	6,433	6,393	6,388	6,398	6,383	6,405	6,427	6,430
220kV	1,969	1,969	1,902	1,902	1,902	1,902	1,886	1,886
380kV	1,076	1,076	1,145	1,145	1,145	1,145	1,252	1,252

Source: VEOE

- No breakdown obtained between line and cable
- Slow overall network growth typical of mature Western European countries

Belgium

	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**8,807**		**8,824**	**8,910**	**8,915**	**9,006**	**9,028**	**9,038**	**9,096**
70kV	3,281		3,274	3,286	3,241	3,229	3,232	3,232	3,259
150kV	3,774		3,760	3,835	3,864	3,918	3,932	3,942	3,973
220kV	357		379	378	378	383	388	388	388
380kV	1,395		1,411	1,411	1,432	1,476	1,476	1,476	1,476
Overhead	**8,524**		**8,484**	**8,530**	**8,522**	**8,590**	**8,595**	**8,605**	**8,619**
70kV	3,134		3,108	3,098	3,040	3,024	3,024	3,024	3,031
150kV	3,638		3,586	3,643	3,672	3,707	3,707	3,717	3,724
220kV	357		379	378	378	383	388	388	388
380kV	1,395		1,411	1,411	1,432	1,476	1,476	1,476	1,476
Underground	**283**		**340**	**380**	**393**	**416**	**433**	**433**	**477**
70kV	147		166	188	201	205	208	208	228
150kV	136		174	192	192	211	225	225	249
220kV	0		0	0	0	0	0	0	0
380kV	0		0	0	0	0	0	0	0

Source: ELIA

- Slow overall network growth typical of mature Western European countries
- Small cable circuit lengths increasing gradually

Canada

	1993	1994	1995	1996	1997	1998	1999	2000
Total circuit length	**120,860**	**122,704**	**122,527**	**122,236**	***134,110***	***135,529***	**127,414**	**128,997**
Up to 109 kV	693	693	693	2,436	*12,808*	*12,832*	10,812	11,540
110 - 149 kV	47,942	48,551	48,360	46,676	*47,004*	*47,493*	45,341	45,467
150 - 199 kV	2,298	2,298	2,298	2,298	*2,298*	*2,298*	2,270	2,270
200 - 299 kV	39,692	40,026	39,982	40,008	*40,890*	*41,433*	39,272	39,604
300 - 399 kV	10,369	10,778	10,836	9,390	*9,545*	*9,801*	9,123	9,123
500 - 599 kV	9,181	9,673	9,673	10,743	*10,880*	*10,985*	9,909	10,228
600 - 799 kV	10,685	10,685	10,685	10,685	*10,685*	*10,687*	10,687	10,765
Overhead	**120,068**	**121,887**	**121,788**	**121,428**	***133,147***	***134,591***	**126,616**	**128,190**
Up to 109 kV	693	693	693	2,434	*12,784*	*12,808*	10,796	11,524
110 - 149 kV	47,417	48,001	47,891	46,144	*46,435*	*46,949*	44,841	44,966
150 - 199 kV	2,273	2,273	2,273	2,273	*2,273*	*2,273*	2,270	2,270
200 - 299 kV	39,536	39,870	39,826	39,846	*40,707*	*41,250*	39,139	39,463
300 - 399 kV	10,359	10,768	10,823	9,378	*9,533*	*9,789*	9,111	9,111
500 - 599 kV	9,105	9,597	9,597	10,668	*10,730*	*10,835*	9,772	10,091
600 - 799 kV	10,685	10,685	10,685	10,685	*10,685*	*10,687*	10,687	10,765
Underground	**792**	**817**	**739**	**808**	***963***	***938***	**798**	**807**
Up to 109 kV				2	*24*	*24*	16	16
110 - 149 kV	525	550	469	532	*569*	*544*	500	501
150 - 199 kV	25	25	25	25	*25*	*25*	0	0
200 - 299 kV	156	156	156	162	*183*	*183*	133	141
300 - 399 kV	10	10	13	12	*12*	*12*	12	12
500 - 599 kV	76	76	76	75	*150*	*150*	137	137

Source: Canadian Electricity Association

- Issues with data consistency (’97 and ’98 show higher figures than other years)
- Almost no cable

China (data for Beijing only)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length										**15,483**
110kV										8,094
220kV										5,055
500kV										2,334
Overhead										**14,304**
110kV										7,104
220kV										4,866
500kV										2,334
Underground	**273**									**1,179**
110kV	267									990
220kV	6									189
500kV	0									0

Source: Beijing Electric

- Extremely limited availability of data
- Large growth in cable over sustained period

Denmark

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**5,856**	**5,806**	**5,981**	**5,997**	**6,028**	**5,992**	**6,061**	**6,125**	**6,164**	**6,219**
30-60Kv	*8,253*	*8,276*	*8,261*	*8,256*	*8,307*	*8,350*	*8,371*	*8,361*	*8,408*	*8,509*
132-400Kv	5,856	5,806	5,981	5,997	6,028	5,992	6,061	6,125	6,164	6,219
Overhead	**5,385**	**5,336**	**5,380**	**5,369**	**5,381**	**5,319**	**5,351**	**5,347**	**5,391**	**5,382**
30-60Kv	*6,620*	*6,605*	*6,536*	*6,471*	*6,387*	*6,338*	*6,243*	*6,145*	*6,107*	*6,087*
132-400Kv	5,385	5,336	5,380	5,369	5,381	5,319	5,351	5,347	5,391	5,382
Underground	**471**	**470**	**601**	**628**	**647**	**673**	**710**	**778**	**773**	**837**
30-60Kv	*1,633*	*1,671*	*1,725*	*1,785*	*1,920*	*2,012*	*2,128*	*2,216*	*2,301*	*2,422*
132-400Kv	471	470	601	628	647	673	710	778	773	837

Source: Dansk Energie
NB Data tracked by network length, not circuit length

- Data aggregated into broad ranges – not possible to get greater breakdown by kV
- Consistency issues with data collation, probably through under-reporting (see 30-60kV range)

Finland

	1993	1994	1995	1996	1997	1998	1999	2000
Total circuit length	**20,612**	**20,846**	**20,996**	**21,096**	**21,235**	**21,428**	**21,287**	**21,486**
110kV	14,600	14,600	14,750	14,850	14,900	14,960	15,000	15,050
220kV	2,660	2,660	2,660	2,660	2,665	2,665	2,510	2,510
400kV	3,352	3,586	3,586	3,586	3,670	3,803	3,777	3,926
Overhead	**20,612**	**20,846**	**20,996**	**21,096**	**21,235**	**21,428**	**21,287**	**21,486**
110kV	14,600	14,600	14,750	14,850	14,900	14,960	15,000	15,050
220kV	2,660	2,660	2,660	2,660	2,665	2,665	2,510	2,510
400kV	3,352	3,586	3,586	3,586	3,670	3,803	3,777	3,926
Underground	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
110kV	0	0	0	0	0	0	0	0
220kV	0	0	0	0	0	0	0	0
400kV	0	0	0	0	0	0	0	0

Source: Sener

- Limited availability of data
- No cable at the kV levels examined

France

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**96,709**	**97,235**	**97,857**	**98,378**	**98,746**	**98,907**	**99,015**	**99,108**	**99,278**	**99,339**
63kV	34,330	34,711	35,035	35,326	35,463	35,410	35,576	35,602	35,715	35,642
90kV	14,432	14,564	14,857	14,825	14,966	15,067	15,197	15,276	15,358	15,393
150kV	1,975	1,775	1,585	1,584	1,458	1,375	1,234	1,223	1,220	1,149
225kV	25,711	25,881	25,861	25,903	26,032	26,204	26,156	26,160	26,108	26,289
400kV	20,261	20,304	20,519	20,740	20,827	20,851	20,852	20,847	20,877	20,866
Overhead	**94,578**	**94,952**	**95,646**	**96,044**	**96,281**	**96,339**	**96,319**	**96,303**	**96,379**	**96,313**
63kV	32,995	33,273	33,675	33,877	33,938	33,842	33,940	33,893	33,953	33,851
90kV	14,268	14,385	14,668	14,633	14,761	14,840	14,938	14,988	15,048	15,060
150kV	1,974	1,774	1,584	1,583	1,457	1,374	1,233	1,222	1,219	1,148
225kV	25,083	25,219	25,203	25,214	25,301	25,434	25,358	25,355	25,284	25,390
400kV	20,258	20,301	20,516	20,737	20,824	20,849	20,850	20,845	20,875	20,864
Underground	**2,131**	**2,283**	**2,211**	**2,334**	**2,465**	**2,568**	**2,696**	**2,805**	**2,899**	**3,026**
63kV	1,335	1,438	1,360	1,449	1,525	1,568	1,636	1,709	1,762	1,791
90kV	164	179	189	192	205	227	259	288	310	333
150kV	1	1	1	1	1	1	1	1	1	1
225kV	628	662	658	689	731	770	798	805	824	899
400kV	3	3	3	3	3	2	2	2	2	2

Source: RTE - CIREF

- Very slow overall growth in circuit lengths, typical of Western Europe countries
- Sustained increase in cable over time

Germany

	1993	1994	1995	1996	1997
Total circuit length	**115,964**	**116,439**	**116,975**	**116,951**	**117,011**
60 kV	1,707	1,458	1,465	1,461	1,481
110 kV	74,230	74,626	74,950	74,796	75,380
220 kV	22,920	22,873	22,678	22,525	21,983
380 kV	17,107	17,482	17,882	18,169	18,167
Overhead	**111,184**	**111,631**	**111,942**	**111,911**	**111,933**
60 kV	1,400	1,173	1,182	1,188	1,253
110kV	69,851	70,202	70,302	70,122	70,621
220kV	22,863	22,826	22,628	22,490	21,949
380kV	17,070	17,430	17,830	18,111	18,110
Underground	**4,780**	**4,808**	**5,033**	**5,040**	**5,078**
60 kV	307	285	283	273	228
110kV	4,379	4,424	4,648	4,674	4,759
220kV	57	47	50	35	34
380kV	37	52	52	58	57

Source: VDEW

- Limited data available
- Mature network growing very slowly in percentage terms

Greece

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**8,945**	**9,040**	**9,295**	**9,407**	**9,520**	**9,591**	**9,894**	**9,959**	**10,886**	**11,026**
66kV	39	39	39	39	39	39	39	39	39	39
150kV	7,047	7,142	7,320	7,431	7,548	7,616	7,705	7,766	8,144	8,258
400kV	1,860	1,860	1,937	1,937	1,934	1,936	2,150	2,153	2,703	2,729
Overhead	**8,822**	**8,917**	**9,172**	**9,284**	**9,397**	**9,454**	**9,758**	**9,822**	**10,749**	**10,876**
66kV	39	39	39	39	39	39	39	39	39	39
150kV	6,923	7,018	7,196	7,308	7,424	7,480	7,568	7,630	8,007	8,108
400kV	1,860	1,860	1,937	1,937	1,934	1,936	2,150	2,153	2,703	2,729
Underground	**123**	**123**	**123**	**123**	**123**	**137**	**137**	**137**	**137**	**150**
66kV	0	0	0	0	0	0	0	0	0	0
150kV	123	123	123	123	123	137	137	137	137	150
400kV	0	0	0	0	0	0	0	0	0	0

Source: Desmie (HTSO)

- Overall network growth typical of mature Western European countries
- Cable apparently used only for very specific applications

Hong Kong

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**368**	**368**	**368**	**368**	**368**	**368**	**368**	**368**	**368**	**368**
132kV	248	248	248	248	248	248	248	248	248	248
275kV	120	120	120	120	120	120	120	120	120	120
Overhead	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**
132kV	20	20	20	20	20	20	20	20	20	20
275kV	0	0	0	0	0	0	0	0	0	0
Underground	**348**	**348**	**348**	**348**	**348**	**348**	**348**	**348**	**348**	**348**
132kV	228	228	228	228	228	228	228	228	228	228
275kV (Submarine)	120	120	120	120	120	120	120	120	120	120

Source: Hong Kong Electric

- Island state with limited space, hence strong tendency to underground
- No growth in period examined

Italy

	1999	2000	2001
Total circuit length	**43,033**	**43,098**	**43,227**
150-132kV	20,340	20,391	20,600
200kV DC	859	859	859
220kV	12,065	12,078	11,998
380kV	9,769	9,769	9,770
Overhead	**42,496**	**42,550**	**42,655**
150-132kV	20,224	20,274	20,469
200kV DC	614	614	614
220kV	11,898	11,902	11,812
380kV	9,760	9,760	9,761
Underground	**537**	**548**	**573**
150-132kV	115	117	132
200kV DC	245	245	245
220kV	167	176	186
380kV	9	9	9

Source: Gestore della Rete di Trasmissione Nazionale

- Limited availability of data
- Slow overall network growth typical of mature Western European countries

Japan

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length										**170,887**
66kV **154kV** **275kV** **500kV**										
										145,887
66kV **154kV** **275kV** **500kV**										
Underground	**12,600**									**16,200**
66kV **154kV** **275kV** **500kV**										

Source: J Power

- Extremely limited data available
- Of the countries examined, installs the highest average annual amount of cable

Malaysia

	2001	2002
Total circuit length	**15,944**	**16,440**
66kV	80	60
132kV	9,596	9,174
275kV	6,218	7,094
500kV	50	111
Overhead	**15,236**	**15,713**
66kV	80	60
132kV	8,928	9,134
275kV	6,178	6,408
500kV	50	111
Underground	**708**	**727**
66kV	0	0
132kV	668	40
275kV	40	687
380 kV	0	0

Source: Tenaga Nasional Berhad

- Very limited data available

Netherlands

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total circuit length	**11,793**	**11,752**	**11,758**	**12,178**	**12,201**		**11,306**	***15,094***	**12,352**
50 kV	2,984	2,978	2,945	3,012	3,119		3,100	*6,128*	2,898
110 kV	1,912	1,932	1,931	2,034	1,961		1,966	*1,902*	1,902
150 kV	4,401	4,428	4,436	4,476	4,496		3,554	*4,378*	4,866
220 kV	848	760	702	677	646		683	*683*	683
380 kV	1,648	1,654	1,744	1,979	1,979		2,003	*2,003*	2,003
Overhead	**8,502**	**8,405**	**8,426**	**8,700**	**8,630**		**7,731**	***8,606***	**8,579**
50 kV	447	436	425	425	459		405	*568*	403
110 kV	1,816	1,820	1,820	1,881	1,808		1,824	*1,761*	1,761
150 kV	3,749	3,741	3,741	3,744	3,744		2,822	*3,597*	3,735
220 kV	842	754	696	671	640		677	*677*	677
380 kV	1,648	1,654	1,744	1,979	1,979		2,003	*2,003*	2,003
Underground	**3,291**	**3,347**	**3,332**	**3,478**	**3,571**		**3,575**	***6,488***	**3,773**
50 kV	2,537	2,542	2,520	2,587	2,660		2,695	*5,560*	2,495
110 kV	96	112	111	153	153		142	*141*	141
150 kV	652	687	695	732	752		732	*781*	1,131
220 kV	6	6	6	6	6		6	*6*	6
380 kV	0	0	0	0	0		0	*0*	0

Source: EnergieNed

- Inconsistent figures in 2000, no data available for 1998 through changes in basis for collation
- Highest proportion in countries examined of cable in transmission network (excluding island states)

Norway

	1993	1994	1995	1996	1997	1998	1999	2000
Total circuit length	**16,835**	**17,374**	**17,945**	**18,260**	**17,414**	**17,107**	***17,285***	**17,469**
33-66kV	11,459	10,801	11,614	11,415	11,966	11,565	11,444	11,304
110-145kV*	9,573	9,956	9,791	9,840	9,744	9,833	*9,887*	9,835
220-300kV	5,262	5,294	6,030	6,233	5,545	5,156	*5,625*	5,860
420kV	2,000	2,124	2,124	2,187	2,125	2,118	*1,773*	1,774
Overhead	**16,122**	**16,569**	**17,225**	**17,574**	**16,728**	**16,850**	***13,987***	**17,143**
33-66kV	10,236	9,721	10,555	10,298	10,886	10,493	10,383	10,244
110-145kV*	9,301	9,603	9,522	9,627	9,530	9,656	*6,655*	9,594
220-300kV	4,837	4,858	5,595	5,781	5,089	5,090	*5,573*	5,790
420kV	1,984	2,108	2,108	2,166	2,109	2,104	*1,759*	1,759
Underground	**713**	**776**	**719**	**686**	**684**	**305**	***298***	**326**
33-66kV	1,223	1,079	1,059	1,117	1,079	1,072	1,061	1,060
110-145kV*	272	324	269	213	213	225	*232*	241
220-300kV	425	436	434	452	455	66	*52*	70
420kV	16	16	16	21	16	14	*14*	15

Source: Stattnet/Statistics Norway

- Data inconsistencies at 33-66kV throughout
- Unusual apparent movement in total cable length and in 1999 overhead data may also be due to data issues (see 33-66kV and 1999)

Portugal

	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**12,473**	**12,844**		**13,123**	**13,256**	**13,471**	**13,892**
60kV	6,706	6,851		7,053	7,167	7,210	7,388
132/142kV	81	66		66	75	66	66
150kV	2,217	2,347		2,413	2,361	2,361	2,420
220kV	2,296	2,347		2,357	2,418	2,599	2,717
400kV	1,173	1,234		1,234	1,235	1,235	1,301
Overhead	**12,166**	**12,519**		**12,746**	**12,885**	**13,105**	**13,520**
60kV	6,399	6,526		6,692	6,811	6,859	7,031
132/142kV	81	66		66	75	66	66
150kV	2,217	2,347		2,409	2,357	2,357	2,417
220kV	2,296	2,347		2,346	2,407	2,588	2,705
400kV	1,173	1,234		1,234	1,235	1,235	1,301
Underground	**307**	**325**		**376**	**371**	**366**	**372**
60kV	307	325		362	356	352	357
132/142kV	0	0		0	0	0	0
150kV	0	0		4	4	4	4
220kV	0	0		11	11	11	11
400kV	0	0		0	0	0	0

Source: EdP

- Limited use of cable
- Slow growth of overall network

Singapore

	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**1,303**	**1,311**	**1,360**	**1,387**	**1,504**	**1,576**	**1,706**	**1,808**
66 kV	836	844	885	893	954	984	1,018	1,097
230 kV	467	467	467	486	487	529	577	600
400 kV	0	0	8	8	63	63	111	111
Overhead	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
66 kV	0	0	0	0	0	0	0	0
230 kV	0	0	0	0	0	0	0	0
400 kV	0	0	0	0	0	0	0	0
Underground	**1,303**	**1,311**	**1,360**	**1,387**	**1,504**	**1,576**	**1,706**	**1,808**
66 kV	836	844	885	893	954	984	1,018	1,097
230 kV	467	467	467	486	487	529	577	600
400 kV	0	0	8	8	63	63	111	111

Source: PowerGrid

- Island state with 100% underground for space and aesthetic reasons

South Korea

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**21,195**	**21,616**	**22,674**	**23,142**	**24,254**	**24,887**	**25,307**	**26,549**	**27,325**	**27,907**
66kV	3,551	3,370	3,193	2,705	2,513	2,319	2,090	1,725	1,540	1,402
154kV	12,084	12,484	13,529	14,181	15,097	15,821	16,064	16,746	17,576	18,144
345kV	5,560	5,762	5,952	6,256	6,442	6,491	6,665	7,281	7,345	7,497
765kV	0	0	0	0	0	54	286	595	662	662
Submarine (180kV)	0	0	0	0	202	202	202	202	202	202
Overhead	**20,623**	**21,003**	**21,953**	**22,308**	**23,048**	**23,525**	**23,889**	**24,943**	**25,538**	**25,896**
66kV	3,533	3,357	3,180	2,693	2,501	2,307	2,078	1,713	1,531	1,398
154kV	11,530	11,884	12,821	13,359	14,154	14,766	14,953	15,447	16,111	16,501
345kV	5,560	5,762	5,952	6,256	6,393	6,398	6,572	7,188	7,234	7,335
765kV	0	0	0	0	0	54	286	595	662	662
Underground	**572**	**613**	**721**	**834**	**1,206**	**1,362**	**1,418**	**1,606**	**1,787**	**2,011**
66kV	18	13	13	12	12	12	12	12	9	4
154kV	554	600	708	822	943	1,055	1,111	1,299	1,465	1,643
345kV	0	0	0	0	49	93	93	93	111	162
Submarine (180kV)	0	0	0	0	202	202	202	202	202	202

Source: KEPCO

- Rapidly growing overall network consistent with other fast-growing Asian economies
- Strong uptake of underground

Spain

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**48,193**	**48,781**	**49,132**	**49,407**	**49,832**	**50,353**	**50,600**	**51,273**	**51,926**	**52,949**
110-132kV	19,267	19,584	19,658	19,798	19,861	19,988	20,134	20,324	20,539	20,706
220kV	15,316	15,460	15,504	15,525	15,728	15,827	15,928	16,031	16,207	16,351
400kV	13,611	13,737	13,970	14,083	14,244	14,538	14,538	14,918	15,180	15,892

Source: UNESA

- Slow overall network growth
- No split between underground and overhead was obtained

Sweden

	1998	1999	2000	2001
Total circuit length	**15,925**	**16,853**	**16,788**	**16,604**
70-130kV	15,919	16,847	16,782	16,593
400kV	6	6	6	11
Overhead	**15,772**	**16,679**	**16,610**	**16,444**
70-130kV	15,766	16,673	16,604	16,438
400kV	6	6	6	6
Underground	**153**	**174**	**178**	**161**
70-130kV	153	174	178	155
400kV	0	0	0	6

Source: STEM

- Very limited data available
- Low use of cable at transmission voltages

Switzerland

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**2,080**	**2,080**	**2,063**	**2,063**	**2,076**	**2,153**	**2,153**	**2,166**	**2,166**	**2,166**
50kV	605	605	592	592	575	575	575	575	575	550
132kV	256	256	252	252	282	295	295	308	308	333
220kV	1,134	1,134	1,134	1,134	1,134	1,198	1,198	1,198	1,198	1,198
380kV	85	85	85	85	85	85	85	85	85	85
Overhead	**2,029**	**2,022**	**1,996**	**1,993**	**1,989**	**2,040**	**2,036**	**2,032**	**2,029**	**1,999**
50kV	570	563	537	534	513	500	496	492	489	459
132kV	240	240	240	240	257	257	257	257	257	257
220kV	1,134	1,134	1,134	1,134	1,134	1,198	1,198	1,198	1,198	1,198
380kV	85	85	85	85	85	85	85	85	85	85
Underground	**47**	**54**	**67**	**70**	**87**	**113**	**117**	**134**	**137**	**167**
50kV	35	42	55	58	62	75	79	83	86	91
132kV	12	12	12	12	25	38	38	51	51	76
220kV	0	0	0	0	0	0	0	0	0	0
380kV	0	0	0	0	0	0	0	0	0	0

Source: BKW (FMB)

- Data available for only one of seven TSOs

Thailand

	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**21,319**	**22,105**	**22,924**	**23,348**	**23,797**	**25,000**	**26,350**	**27,040**	**28,195**
69 kV	324	303	177	140	140	52	52	52	224
115 kV	10,972	11,526	12,123	12,487	12,652	13,127	13,712	13,939	13,903
132 kV	9	9	9	9	9	9	9	9	35
230 kV	8,813	9,066	9,198	9,295	9,352	10,054	10,445	10,907	11,220
300 kV DC	0	0	0	0	0	0	0	0	24
500 kV	1,201	1,201	1,417	1,417	1,644	1,758	2,132	2,132	2,790
Overhead	**21,319**	**22,105**	**22,924**	**23,348**	**23,797**	**25,000**	**26,350**	**27,040**	**27,968**
69 kV	324	303	177	140	140	52	52	52	52
115 kV	10,972	11,526	12,123	12,487	12,652	13,127	13,712	13,939	13,873
132 kV	9	9	9	9	9	9	9	9	9
230 kV	8,813	9,066	9,198	9,295	9,352	10,054	10,445	10,907	11,220
300 kV (DC)	0	0	0	0	0	0	0	0	24
500 kV	1,201	1,201	1,417	1,417	1,644	1,758	2,132	2,132	2,790
Underground									**228**
69 kV									172
115 kV									29
132 kV									26
230 kV									
300 kV (DC)									
500 kV									

Source: EGAT

- Fast overall network growth consistent with other growing Asian economies
- TSO is currently collating underground data but could not provide it for this study

United Kingdom

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total circuit length	**14,059**	**14,172**	**14,209**	**14,239**	**14,308**	**14,319**	**14,373**	**14,365**	**14,413**	**14,532**
Other	13	13	13	13	13	13	13	13	13	14
132kV	357	259	257	253	253	253	253	252	252	254
275kV	3,801	3,765	3,766	3,777	3,772	3,784	3,819	3,762	3,806	3,909
400kV	9,888	10,135	10,173	10,196	10,270	10,269	10,288	10,338	10,342	10,355
Overhead	**13,450**	**13,563**	**13,591**	**13,620**	**13,689**	**13,699**	**13,752**	**13,740**	**13,786**	**13,906**
Other	8	8	8	8	8	8	8	8	8	9
132kV	294	196	196	192	192	192	192	192	192	190
275kV	3,387	3,351	3,341	3,352	3,347	3,358	3,392	3,335	3,377	3,484
400kV	9,761	10,008	10,046	10,068	10,142	10,141	10,160	10,205	10,209	10,223
Underground	**609**	**609**	**618**	**619**	**619**	**620**	**621**	**625**	**627**	**626**
Other	5	5	5	5	5	5	5	5	5	5
132kV	63	63	61	61	61	61	61	60	60	64
275kV	414	414	425	425	425	426	427	427	429	425
400kV	127	127	127	128	128	128	128	133	133	132

Source: National Grid

- Slow overall network growth typical of mature Western European countries

USA

	1995	1996	1997	1998	1999	2000	2001
Total circuit length	**733,564**	**731,629**	**743,000**	**731,484**	***874,635***	**737,101**	***874,635***
51-70 KV	170,374	170,124	171,727	169,053	*261,760*	168,523	*261,760*
71-131 KV	155,199	155,426	157,421	160,108	*171,390*	160,243	*171,390*
132-143 KV	121,411	120,038	121,795	119,289	*128,687*	122,947	*128,687*
144-188 KV	40,667	40,621	40,628	40,969	*46,495*	39,223	*46,495*
189-253 KV	111,923	111,927	113,276	115,773	*125,424*	118,405	*125,424*
254-400 KV	85,072	84,578	88,495	76,109	*89,141*	76,409	*89,141*
401-600 KV	42,651	42,648	45,124	45,778	*47,305*	46,918	*47,305*
OVER 600 KV	6,267	6,267	4,534	4,406	*4,433*	4,433	*4,433*
Overhead	**720,973**	**720,671**	**730,065**	**716,506**	***866,515***	**728,843**	***866,515***
51-70 KV	167,943	167,417	168,898	165,931	*259,910*	166,813	*259,910*
71-131 KV	151,762	151,989	152,882	155,373	*170,081*	158,772	*170,081*
132-143 KV	116,481	116,476	117,823	114,137	*125,080*	119,312	*125,080*
144-188 KV	40,657	40,611	40,607	40,928	*46,322*	39,050	*46,322*
189-253 KV	111,201	111,205	112,362	114,547	*124,635*	117,572	*124,635*
254-400 KV	84,023	84,070	87,849	75,422	*88,748*	75,987	*88,748*
401-600 KV	42,639	42,636	45,110	45,763	*47,305*	46,904	*47,305*
OVER 600 KV	6,267	6,267	4,534	4,406	*4,433*	4,433	*4,433*
Underground	***12,591***	***10,958***	***12,935***	***14,978***	***8,120***	**8,258**	***8,120***
51-70 KV	*2,431*	*2,706*	*2,829*	*3,123*	*1,850*	1,709	*1,850*
71-131 KV	*3,437*	*3,437*	*4,539*	*4,736*	*1,309*	1,471	*1,309*
132-143 KV	*4,930*	*3,563*	*3,972*	*5,152*	*3,607*	3,635	*3,607*
144-188 KV	*10*	*10*	*21*	*41*	*172*	174	*172*
189-253 KV	*722*	*722*	*914*	*1,226*	*789*	833	*789*
254-400 KV	*1,049*	*508*	*645*	*687*	*393*	422	*393*
401-600 KV	*12*	*12*	*14*	*14*	*0*	14	*0*
OVER 600 KV	*0*	*0*	*0*	*0*	*0*	0	*0*

Source: Edison Electric Institute

- Highly fragmented TSO market in US that is not required to submit data
- Very difficult to reconcile the data internally, due to known issues with collation process (see Underground data, 1999 and 2001)