Undergrounding HV and EHV – Window of Opportunity Opens

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Welcome to the final session in the Overhead - Underground Update.

In the next forty minutes, I want to explore with you what is happening in the deployment of the high-voltage transmission network across the world.

As you can see from the title of this presentation, it is our view that there may be a worthwhile business opportunity for cablemakers here.

Perhaps at the end of the session we will hear what the view of the ICF membership is.

Definitions

- Generation, Transmission, Distribution
- High Voltage and Extra-High Voltage
- Transmission System Operator
- Circuit kilometres
- Installed costs and lifetime costs

Firstly then, a few definitions.

We have carried out an investigation into the transmission network – the network which links power stations to the much longer distribution network.

We have focused on voltages which are typically labelled high voltage and extra high voltage. In practise the network data relates to 50 kV and above.

We have investigated the network policies of the companies which run the networks at these voltages, mostly these are called TSO's; the organisations operating a country's national grid.

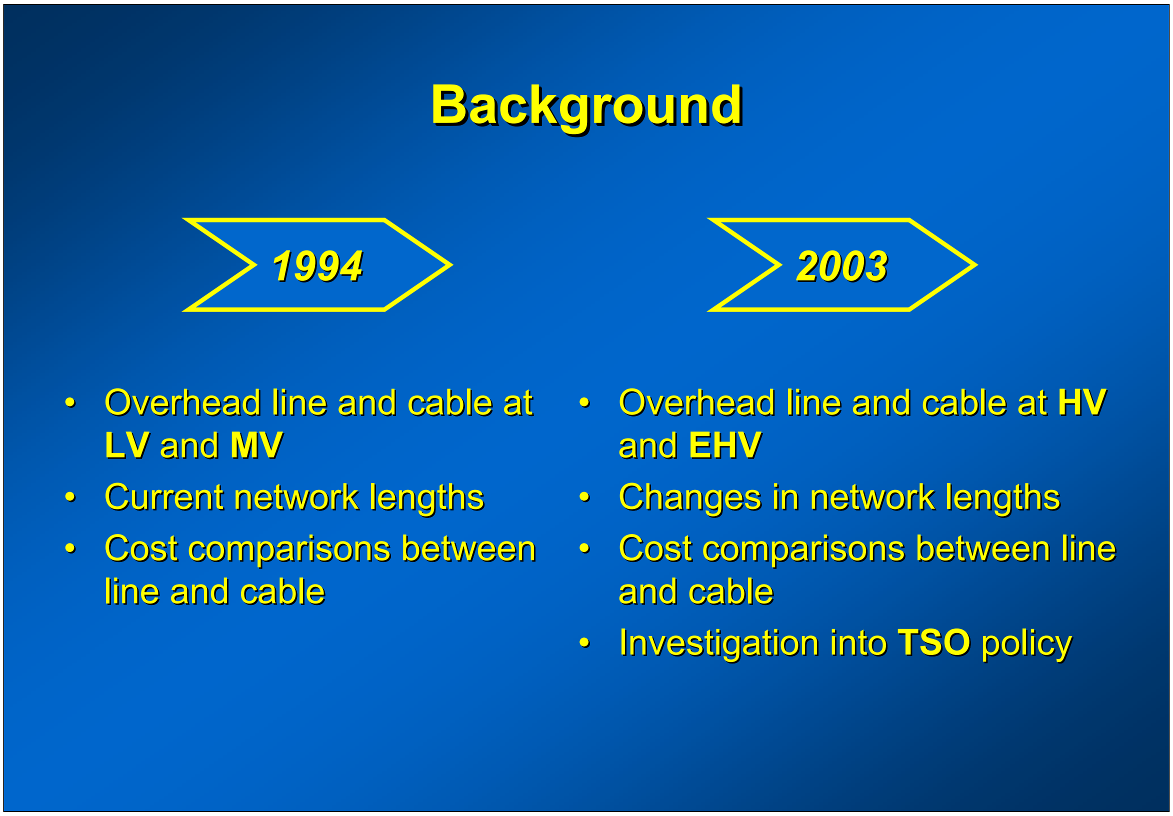
There are two metrics the investigation has focused on:

- 'circuit km' and 'installed versus lifetime cost'.

Circuit km is the metric which measures the length of separate circuits in the network at any voltage level. It differs from the network length as there may be several circuits connecting any two points on the network.

Installed costs are presented in thousands of € per circuit km. They measure what it costs to install a km of overhead line or cable.

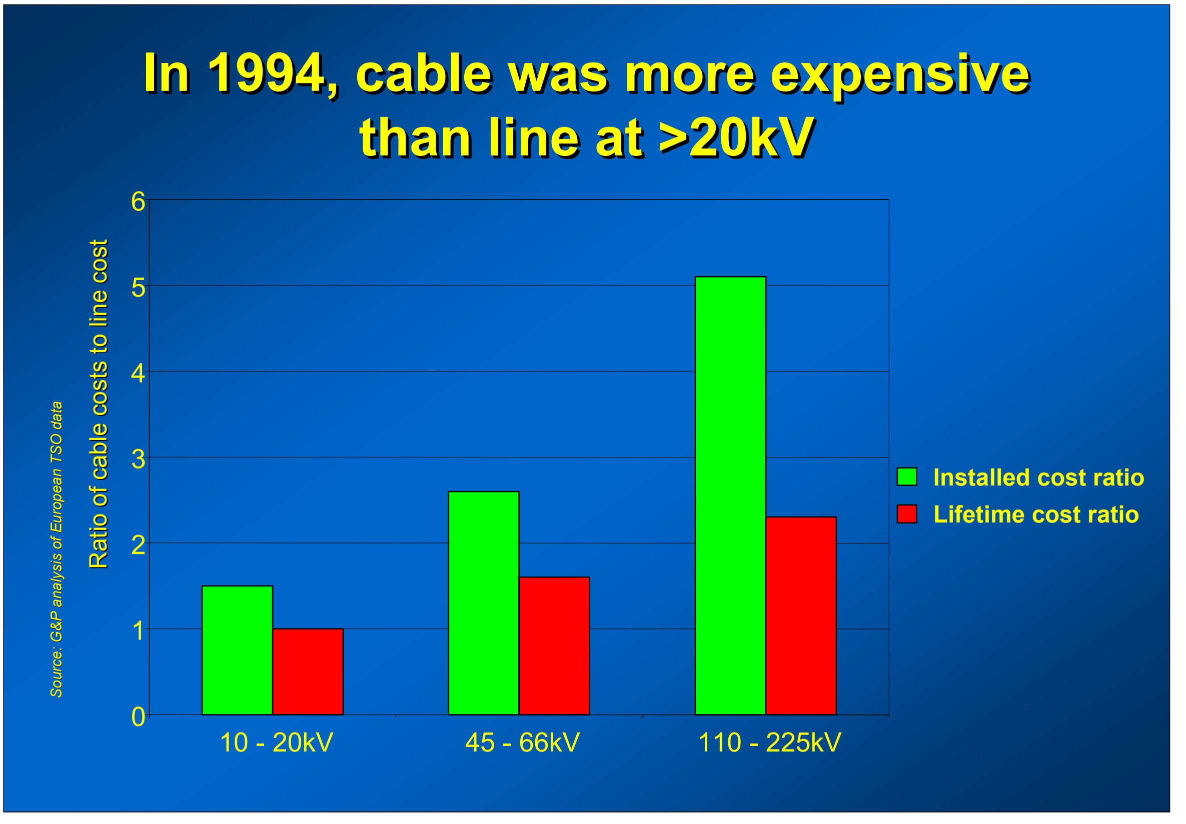
Lifetime costs include both the installed cost and the cost of operating the network over thirty years, discounted to what that cost is in today's money.



This session is called an update because at the ICF 1994 Conference Gorham & Partners presented the then economic and business case for electricity utilities to put new or existing network underground.

The focus then was on the main part of the network by length – low and medium voltages. We got a quantified picture of the length as at 1992 / 1993 and we also sought published studies from the (mainly European) utilities on the relative costs of line and cable.

The 2003 update by comparison has concentrated on 50 kV and above, on the changes in the lengths of the underground and overhead networks over 50 kV, on the economics of line versus cable, at 50 kV upwards, and on gaining a detailed understanding of what TSOs network policy is at these kV levels, in North America, Europe and Asia.



This slide shows the installed cost ratios and corresponding lifetime cost ratios which came out of our 1994 investigation.

They show the ratio of cable to line costs in each voltage range.

As you can see, the installed cost ratio was greater that 1 in each case of the three voltage ranges. But at the lifetime cost level cable was equal to line. If a utility was willing to take thirty years operating costs into account, for all voltages up to 20 kV, there was a strong financial case to consider cable.

In 1994 we discovered that there were many utilities, especially in Europe, which had looked in detail at the comparative costs of line and cable up to 20 kV and were starting to act on it. That process continues today.

Installed costs for cable are higher, operation and cost of losses lower

- Higher installed costs
  - Cost of cable vs. cost of line
  - Tunnels, trenching or ducting
  - Splices and terminations
- Lower operation costs and cost of losses
  - Less affected by weather
  - Less frequent breaks (but longer repair time)
  - Reduced heat transfer and losses

What were the underlying reasons for this pattern?

Firstly, installed costs for cable tended to be higher than line as cable itself costs more than the equivalent line.

Secondly, and one can see this intuitively, the civil engineering costs of digging a trench or putting in a duct or, in some cases, building a tunnel are almost always costlier than putting up a bare conductor between two pylons.

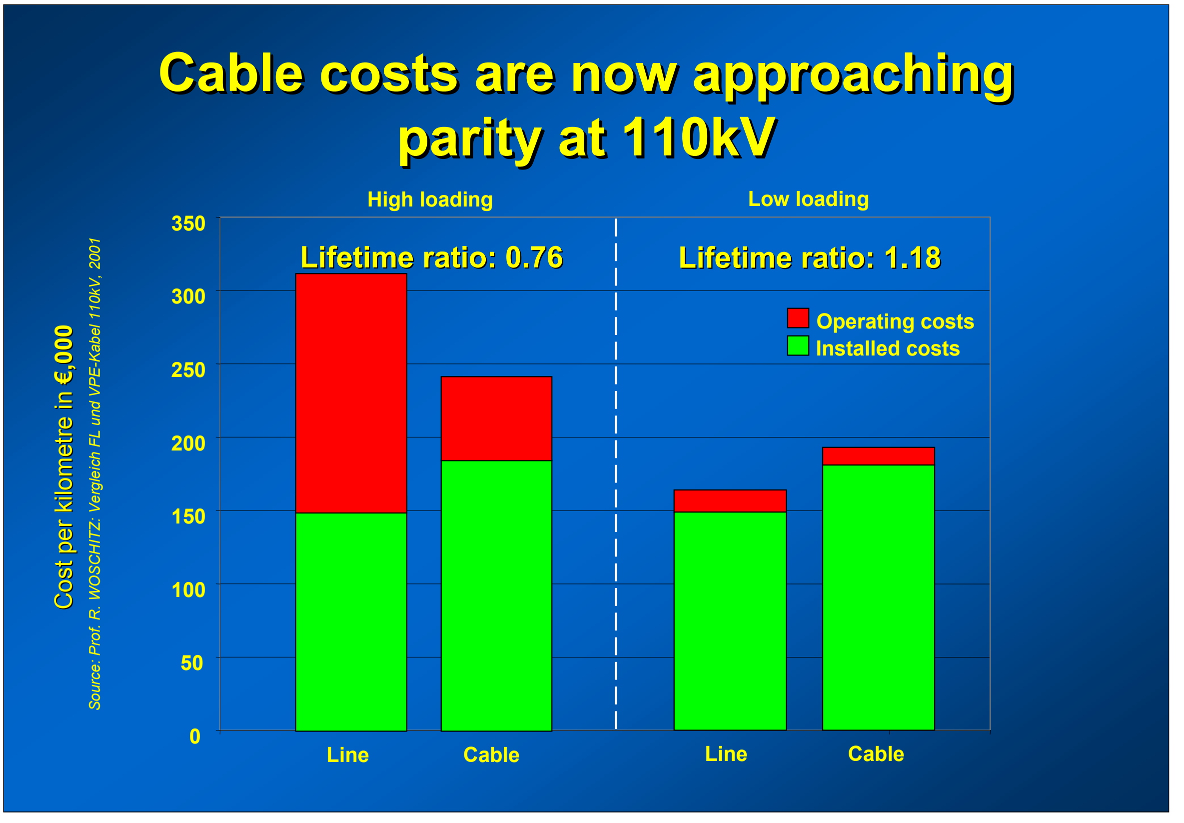
There are also additional material and labour costs associated with connecting two cable lengths together (joints).

Where cable won against line was in its cost of operation.

There are two main costs headings: Maintenance and repair, and the cost of losses.

Maintenance and repair is higher overall for lines as they are exposed to weather and other external events.

Losses for cable are lower as a cable will always have a bigger cross-section, and hence a lower resistance, than the equivalent line.



This slide summarises the findings of the most comprehensive recent study into the comparative costs of line versus cable at high voltage levels. It is based on actual cost data collected from all Austrian utilities operating 110 kV network and was carried out by the Technical University of Graz.

It considers the lifetime costs of these installations under two operating conditions – low current loading and high current loading. Low loading means that the average current carried during the year is a low percentage of the current capacity of the line or cable, and that the current flows in the line on average between three and four hours a day over the year. High loading means that the line or cable carries circa 70-80% of its maximum capacity for circa 15 hours a day.

What we see here is that at the installed cost level, line costs less (150,000 €/ circuit km for line, circa 180,000 €/ circuit km for cable) but that at a high loading, the operating costs of line are significantly greater so that the lifetime ratio for high loading is well below one.

Even at low loading, the ratio is approaching parity. In the judgement of the author of the study, many TSOs will be operating at the high loading end of the spectrum. In the full report which will be circulated to ICF members later in the autumn, we will be including all the cost data collected from TSOs (mainly European) during the investigation. This data is still coming in but the overall message is that in the range 50 – 110 kV TSOs are approaching parity at the lifetime cost ratio level.

What we found in talking to TSOs about costs at high voltage is most interesting and relevant to how cablemakers may wish to take this investigation forward:

•All TSOs quoted overhead/cable HV cost ratios at the installed level but none had detailed cost data on both the line and equivalent cable installation to back them up

•Only a few of the TSOs had any cost ratios which were based on anything more compelling than anecdotal evidence.

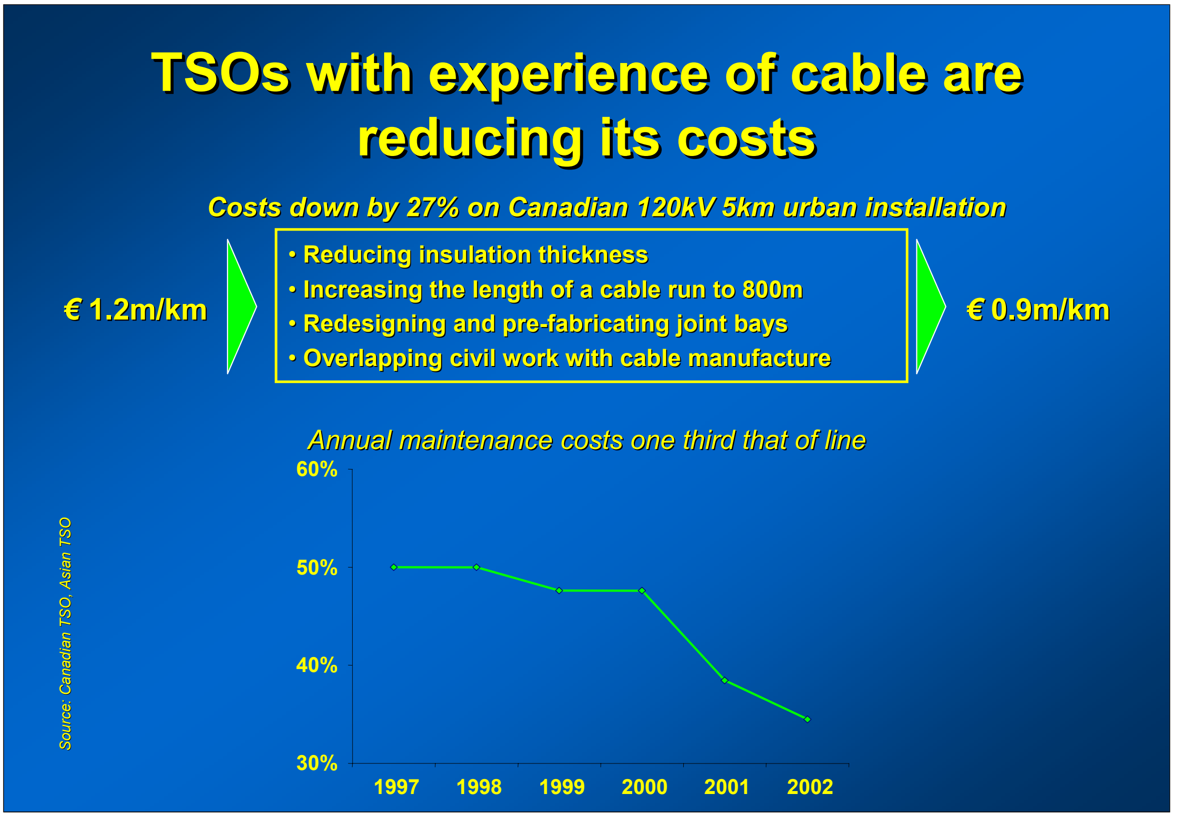
•Even where they had internal cost ratios, only in some cases where they were able to back this up with the actual costs.

•Even where the costs were available, none of the twenty TSOs we met had any data on lifetime costs.

•We found just one of the TSOs was embarking on a joint investigation at 110 kV into the comparative costs of line vs cable at the installed and lifetime cost level

This is a very different situation to what we discovered ten years ago at low and medium voltages. Then we obtained 17 separate utility studies comparing cable and line costs at mainly low and medium voltages carried out by the utilities themselves.

TSOs in 2003 have not looked at the high voltage cost comparison of cable versus line with any rigour at all. They are unaware of the results I have just presented to you on this slide. Interestingly, although the TSOs have hardly any cost comparative data, most of them have installed cable at 50 kV and upwards. Some are looking hard at how they can bring cable costs down.



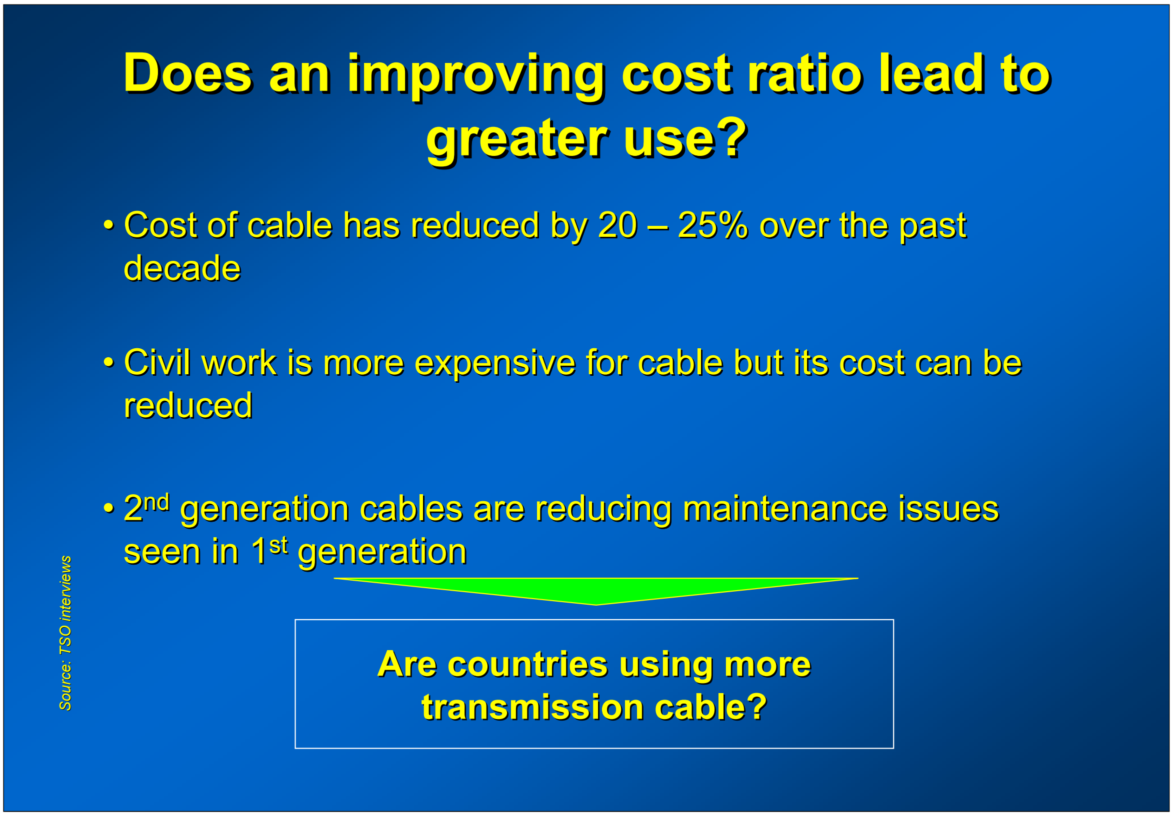
Here are two success stories in reducing cable costs.

Here's a Canadian example of a TSO working in partnership with a cable maker and together they achieved an overall reduction in the installed costs of 27%.

By working closely together, they were able to reduce the cost of the cable by reducing its insulation thickness and increase the cable runs for installation up to 800m. They also reduced the cost of the joint bays through re-design and prefabrication and by carefully coordinating the manufacture of the cable with installation were able to reduce the total project time and hence cost.

The graph in the lower half of the slide shows the improving performance of cable against line in annual maintenance costs. This is the experience of an Asian TSO that has been using cable extensively in renewing and extending its high voltage network. As you can see from the graph, the TSO has succeeded in reducing the maintenance costs from 50% of the line maintenance costs five years ago to ca. 30% today.

What these two examples suggest is that when a utility focuses on cost reductions for cable, they can achieve really significant savings.



So cost ratios are coming down to levels which make cable economically attractive and TSOs are finding ways of narrowing the gap further on specific projects.

Have TSOs and utilities acted on this?

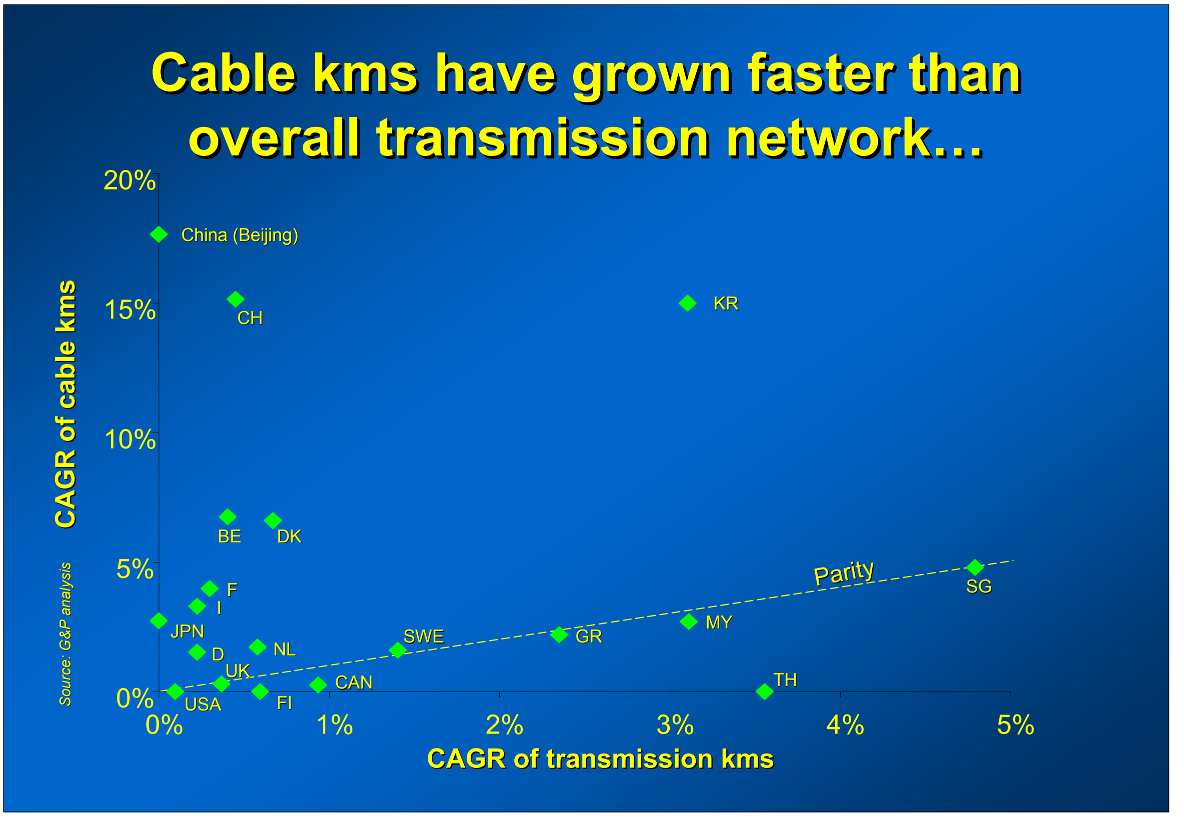
•They are aware that high voltage cable prices have reduced.

•They know that by focusing on the civil costs of cable installation, installation cots can be reduced

•And there is general acceptance that the XLPE product at 100kV is consistent and is reducing maintenance costs.

Have all of these trends fed through into growth in the use of transmission cable? If it has, we would expect it to be visible in the network metrics across most countries. Before we look at the evidence from the network metrics we have collected from twenty countries, I'd like to try to paint a picture in words of what we are dealing with here. Imagine the electricity transmission and distribution network in twenty major countries. It has a circuit length of circa 50 million kilometres. We are interested in that part of the network at 50 kV and above, i.e. 50 kV, 90 kV, 110 kV, 132 kV, 150 kV, 220 kV, 380/400 kV, 700 kV. That's roughly one million circuit kilometres. It splits roughly into 96% line and 4% cable.

So the high voltage cable network in the mid 1990's in these 20 countries was circa 40,000 circuit kilometres, so what is happening to the size of the high voltage network?



If we look at the rate of growth of the cable network over 50 kV, it is growing much faster that the network as a whole.

This slide shows all the countries we have investigated in North America, Europe and Asia positioned on the x-axis by the rate at which their high voltage network, as a whole, has been growing since 1992 /1994, and on the y-axis the rate at which the high voltage cable network has been growing. You can see that the y-axis is five times the scale of the x-axis. The dotted line is the 'parity line' – a country on this line is growing its high voltage network and high voltage cable network at the same rate.

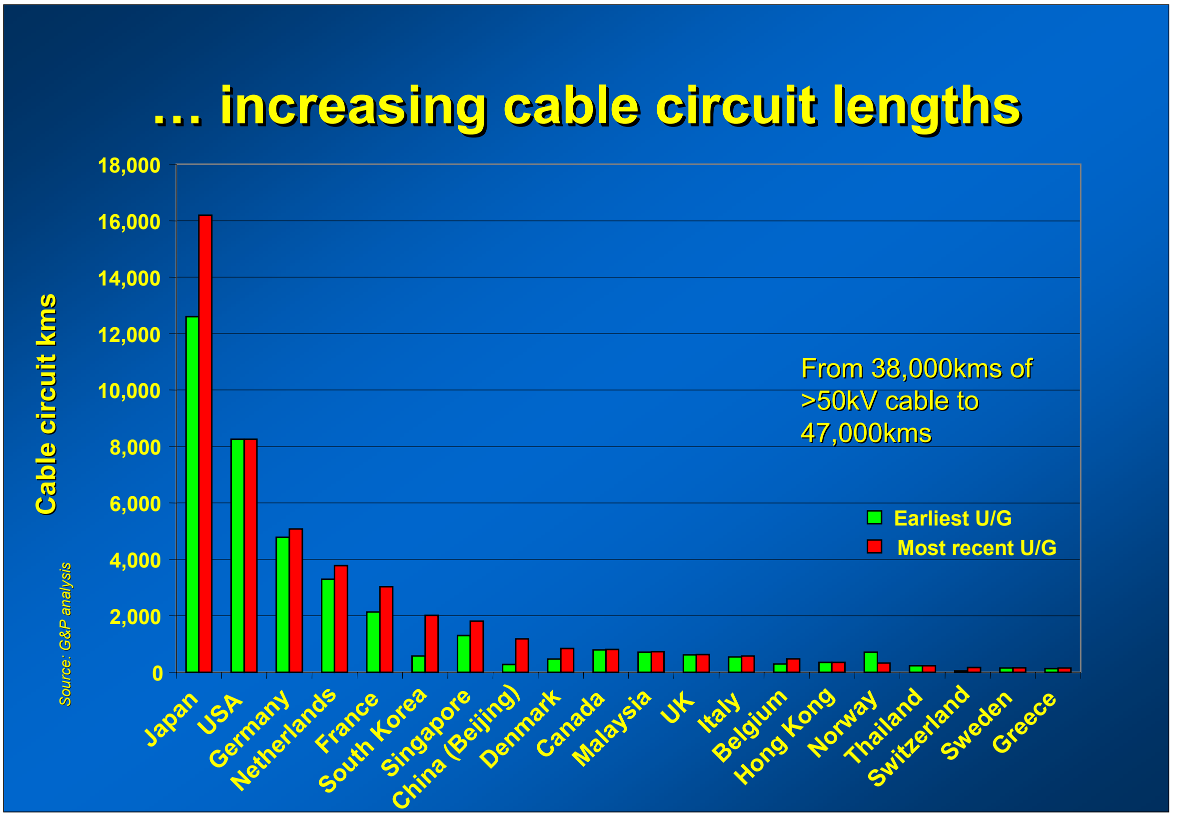
What are the messages from this slide?

•Well, visually we can see that many countries are growing their high voltage cable networks faster than their high voltage networks as a whole.

•In some cases, the growth rate is very much greater. For example, South Korea 15% p.a. versus 3%, Belgium and Denmark 7% p.a. versus under 1%.

•Many developed countries (France, Italy, Germany, Holland) have high voltage cable network growth at 2-5% p.a. and high voltage network growth at under 0.5% p.a.

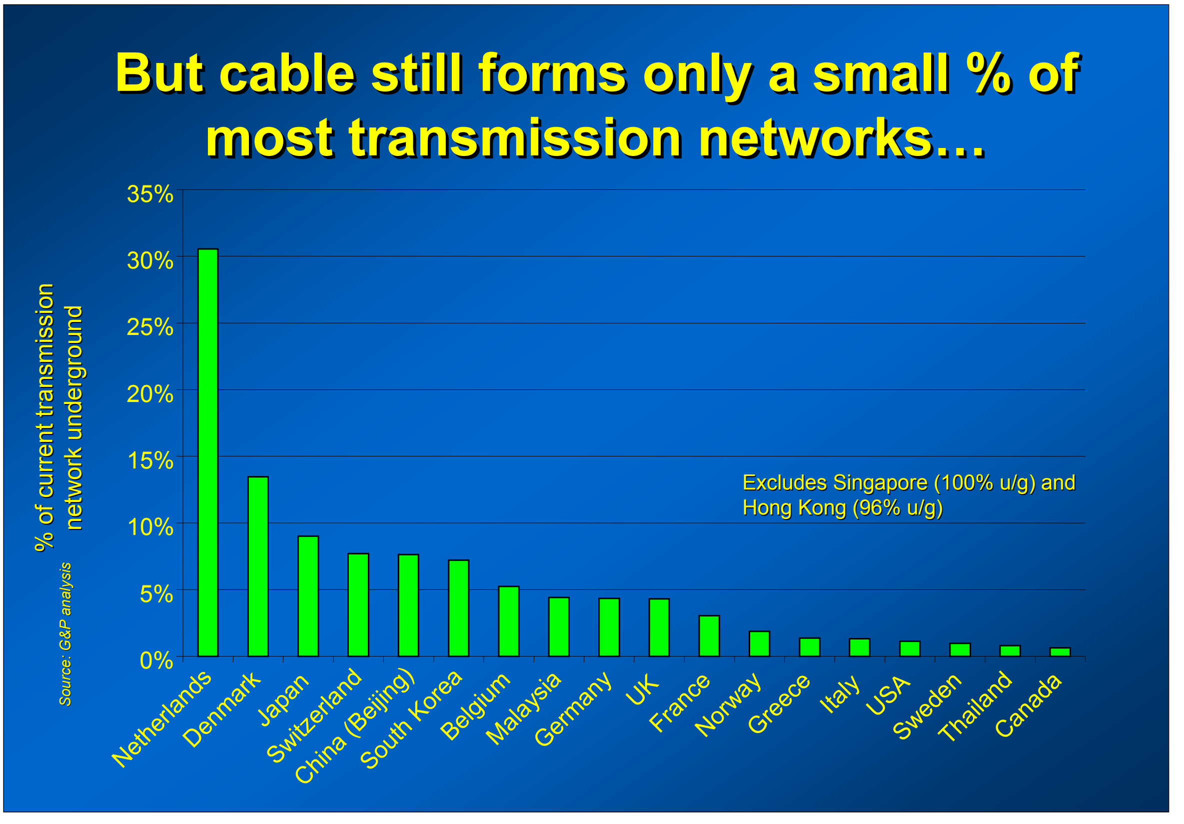
•Headline over this slide is "Cable grows its share of high voltage network".



This slide shows the circuit kilometres of high voltage cable installed by countries in the mid 1990's and in 2002.

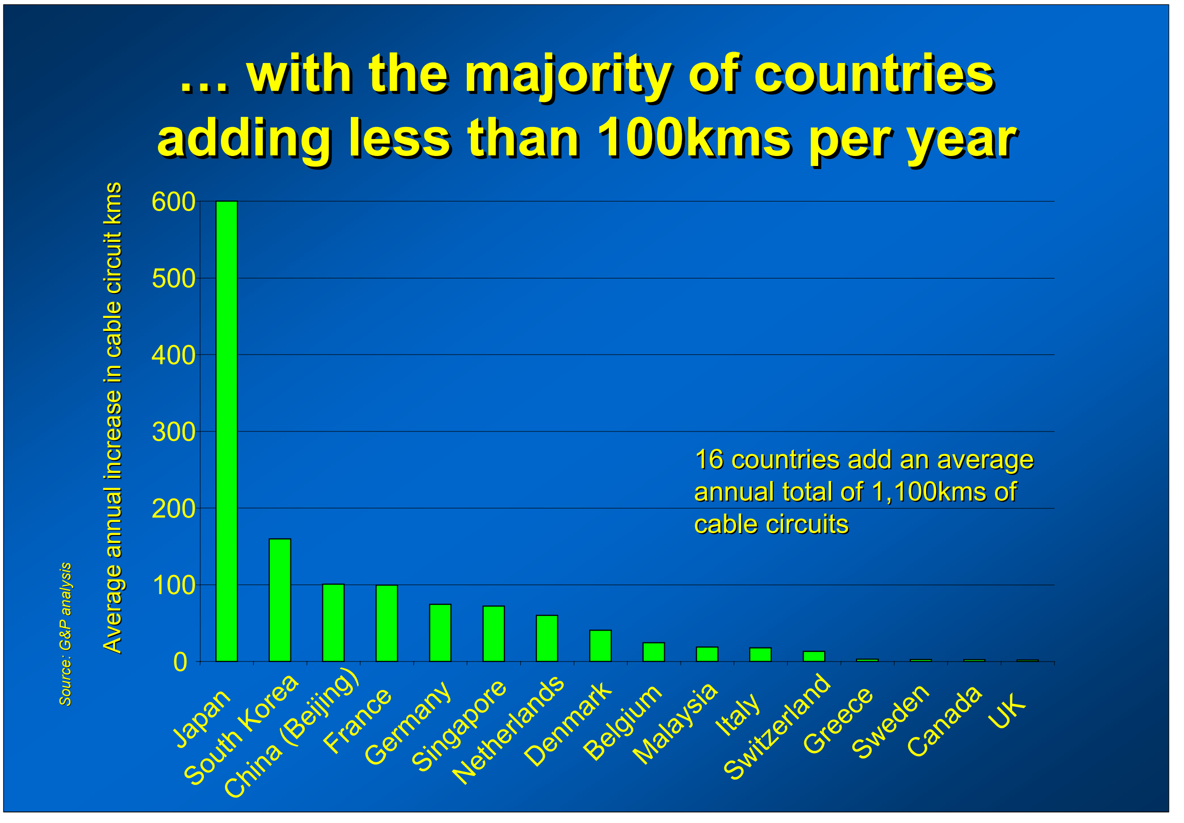
Countries are split into two rough groups:

The overall increase has been zero or marginal in most countries (USA, Canada, Malaysia, UK, Italy, Hong Kong, Norway, Sweden, Thailand, Greece). But there have been significant increases in Japan, Germany, Netherlands, France, South Korea, Singapore, China (Beijing data only), Denmark and Belgium.



Over time these differing growth rates and annual increases have produced a wide variation in the percentage of the high voltage network in cable.

Eleven countries have a cable penetration of below 5%. But seven have more than 5% - Netherlands, Denmark, Japan, Switzerland (1 TSO's data only), China (Beijing), South Korea and Belgium.



So despite cable taking a larger share of the high voltage network over the last ten years and cable lengths growing, the high voltage cable network still forms a very small percentage of the overall high voltage network and most countries annual installation is less than 100 km p.a.

But – think positive!

Turn this around to look at the potential represented by the most advanced countries:

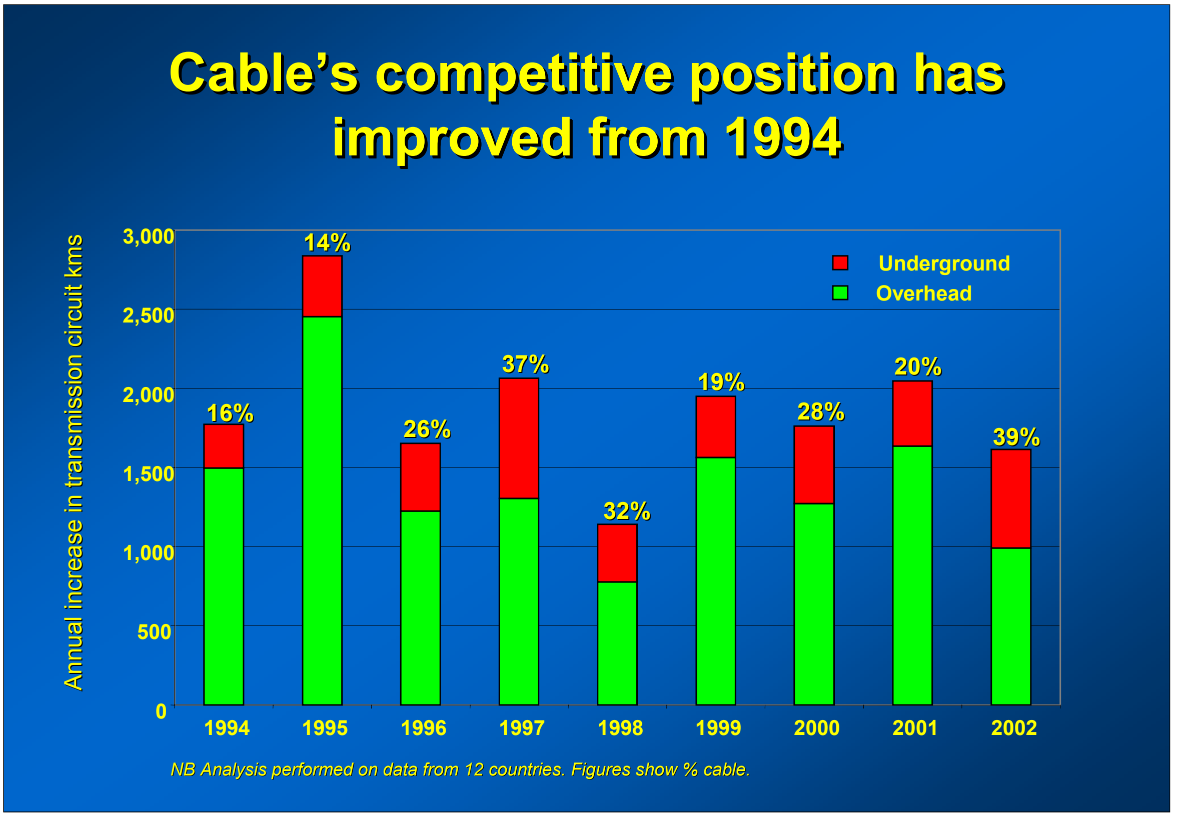
•Three countries have over 10% of high voltage network as cable.

•High voltage network is roughly 1,000,000 circuit kilometres.

•10% of that is 100,000 kilometres.

•Today there are 48,000 kilometres.

•Giving a potential 50,000 kilometres of incremental HV cable if we were to set a target of 10% cable across all these countries



Could this be possible?

Our final slide on metrics concerns cable's share of the annual market for high voltage cable. This slide shows the percentage of cable holds of the annual circuit kilometres installed at 50 kV and above.

The slide suggests that cable has improved its share from ca 15% of annual HV installations in the mid 1990's to a level in the 25-35% range today. In absolute figures it looks as if the annual demand from these countries has grown from 300-450 ct km to 500-600 ct km.

So cable seems to take significant market share away from line over this ten year period.

Key messages from network metrics

- 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

Do improving cost ratios account for all cable growth?

So what are the key messages from the network metrics?

Firstly that within a very slow growing high voltage network, the high voltage cable network is increasing much faster.

High voltage cable is taking share away from line in the annual investment to the network.

But although more high voltage cable is being installed, it is still in relatively low annual amounts.

Most significantly, there are large differences between countries in the extent of high voltage cable usage.

So at the conclusion of this second tranche of evidence, we were still puzzled. If cost ratios were the only driver of cable growth, why does cable's performance vary so much between countries? The improving cost ratios are surely the same world wide?

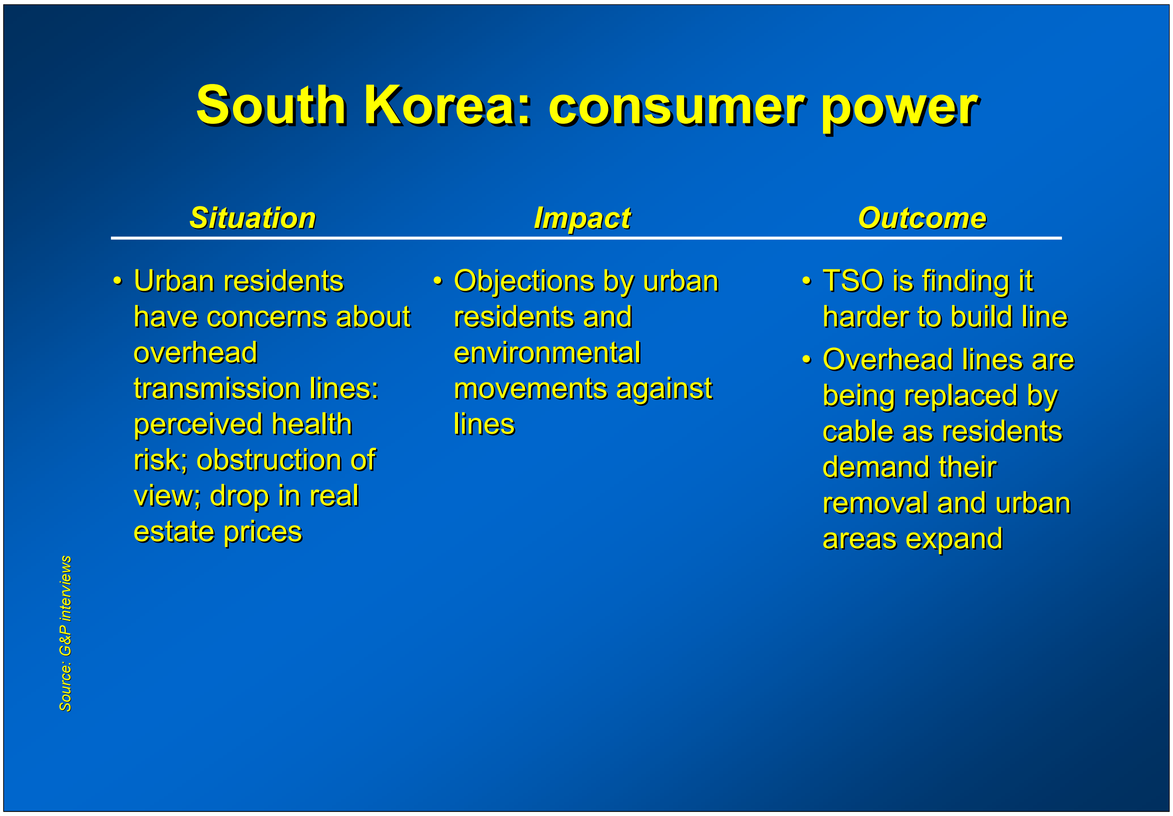
Improving costs is necessary, but is it sufficient?

- Total length of cable at >50 kV has increased since 1993
  - Asia 40% increase
  - Europe 16% increase
  - North America <1% increase
- But regions have adopted transmission cable to different degrees
  - Asia 9% of network underground
  - Europe 3% of network underground
  - North America 1% of network underground
- Are there influences other than cost that affect TSOs' choice?

The meetings we held in North America, Europe and Asia led us to conclude that there are different factors operating on the TSOs in each of these three regions. When we looked at the network metrics separately very big differences are apparent.

The length (in circuit kilometres) of the high voltage cable network has grown by very different amounts between these three regions – in Asia by 40%, but in North America by less than 1%. This ten year change comes through in the figures on the percentage of high voltage cable holds of the high voltage network; in Asia 9%, in Europe 3% and in North America 1%.

Intuitively, it seems that the openness to cable is much greater in Asia. Our meetings with TSO executives in these three regions revealed what lay behind these differences. In each region, different factors influence the network policy of TSOs on what they install at high voltage levels and above.



We have chosen three countries as being broadly typical of the external influences in their region and how they impact TSO policy. For Asia, South Korea; for Europe, Sweden and for North America, USA

All TSOs have a more or less identical "default" policy for their high voltage network. What is that policy? "We choose overhead line rather than underground cable (except in urban areas) in order to save on construction costs."

South Korea:

Here the TSO has had to recognise that the standard TSO policy stated to us by everyone of the twenty TSOs we met is under pressure from the end consumer.

So despite unfavourable lifetime cost ratios at 154 and 345 kV between 2 and 3 and installed cost ratios of 7 to 10, the TSO has had to take into consideration the strong feelings of residents who oppose existing HV lines and were prepared to demonstrate against them. The TSO has adopted a policy of replacing HV lines with cable in response to residents demands. This revised policy has resulted in significant growth in the HV cable network.

Sweden: regulation and consultation

Situation	*Impact*	*Outcome*
• Environmental legislation passed in 1998	• Overhead rights of way for overhead no longer automatically renewed • TSOs required to consult local residents to justify replacement lines • Regulator makes final decision with no right of appeal	• TSO starting to look more favourably on cable

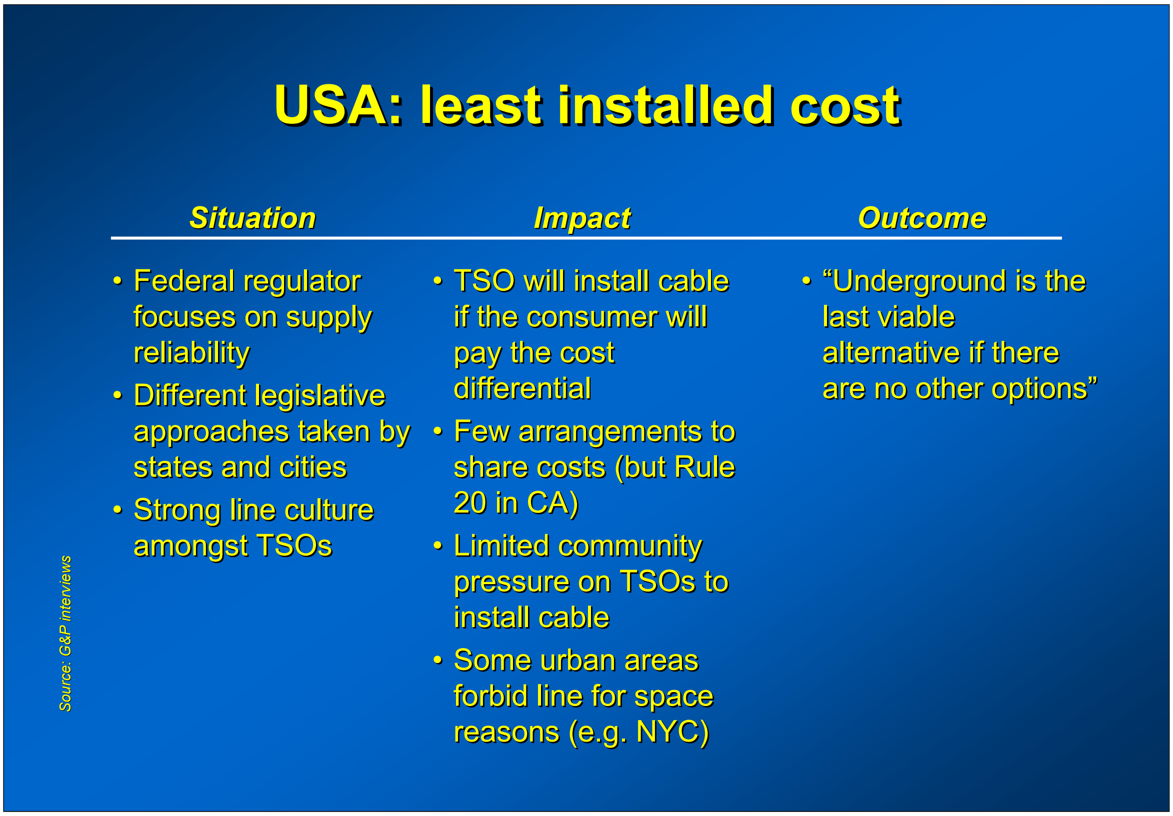
Source: G&P interviews

In Sweden, the TSO is gradually recognising that they too will have to modify their ‘overhead only’ policy. The driver here has been environmental legislation passed in 1997. This requires that when a right of way expires, the TSO re-applies for the right of way as if it were a new line. There is no automatic renewal. This is linked to a rigorous consultation process which has two important characteristics:

•Local residents opinions must be taken into account.

•The regulator takes the final decision and there is no right of appeal.

The new legislation is starting to have an effect in that renewals will be shortly coming through where line has been turned down. The outcome is that the TSO is now starting to review its “line only” policy – they are starting to recognise that a TSO cannot operate a network policy indefinitely which is diametrically opposed to the wishes of its final customers.



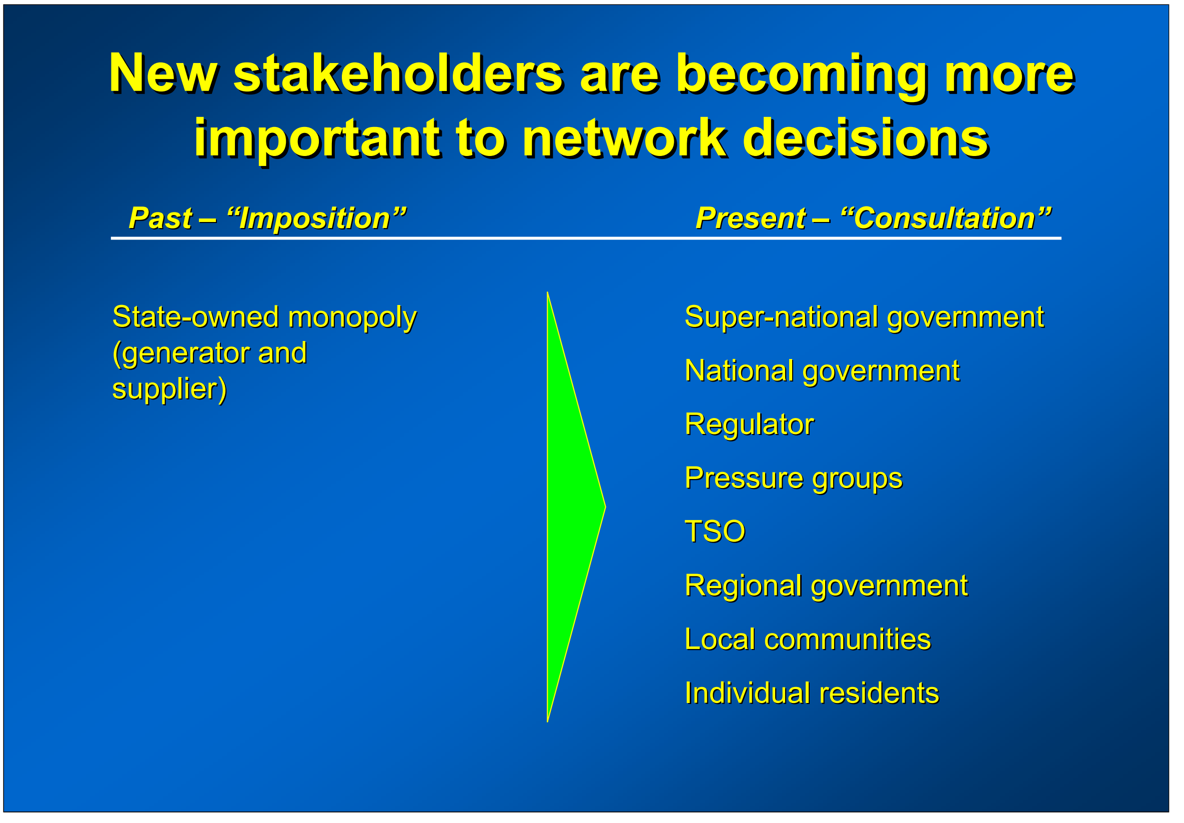
The USA is the country where the federal regulator, plus state and city legislation has had the least impact on network decisions of any country investigated. Why?

•FERC is not seen as particularly strong and and there is variation in the legislative approach at state / city level

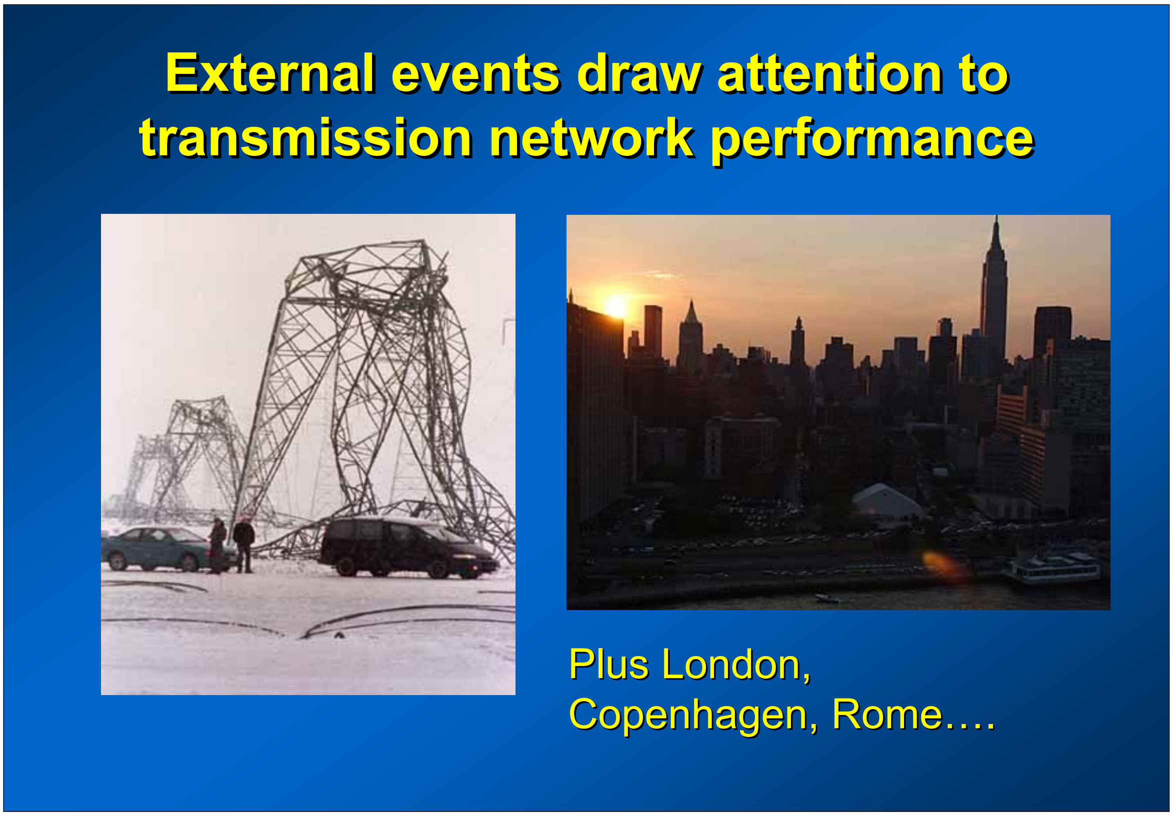
•Compare Louisiana where overhead line is allowed in cities , and California's rule 20 requiring consultation for renewals and new lines in defined areas.

•All this is coupled with relatively low pressure from communities.

•Most important of all is the overwhelmingly strong line culture of US utilities and the fact that there is no single TSO. To quote a top executive from one of the TSOs we met: "Underground is the last viable alternative if there are no other options."



So our conclusion is that it is NOT cost ratios which are driving the growth in high voltage cable. It is the irreversible shift in decision making power from the TSO having absolute power to power sharing between a wide range of other stakeholders. The state is the only 'actor' in network policy decision-making with more power than state-owned monopoly utilities. The state through legislation and regulation is formalising new decision-making processes for the HV networks based on consultation. These give more weight to the wishes of other stakeholders. Often the final decision on a network project lies outside the TSO. What one might call "consultation with teeth" is emerging in many countries across the world.



So these changes play in favour of cablemakers.

Also of potential help to cable are the recent breakdowns in the transmission network in the USA, UK, Scandinavia and Italy.

These events can only raise doubts in the minds of ‘non-experts’ as to whether network failure and predominantly line networks at high voltage are in some way connected.

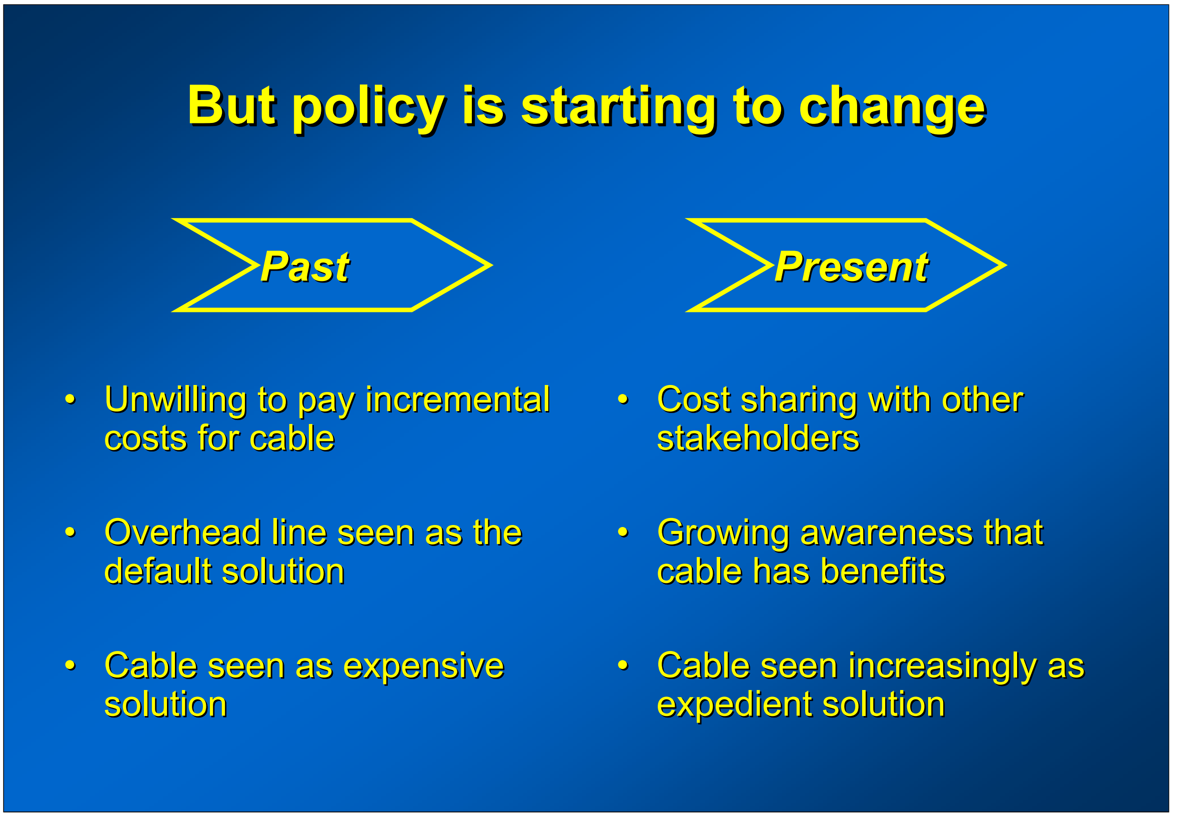
TSO policy does not historically favour cable at >50kV

- TSOs do not consider cable unless they are forced to
- TSOs do not routinely evaluate cable against overhead
- TSOs lack awareness of current cost ratios

Despite all this we shouldn’t kid ourselves. TSOs have a long and successful record of delivering high voltage and extra high voltage power via overhead line networks. Their culture is pro-line, not pro-cable.

TSOs as a result do not even consider cable at HV and EHV unless they are constrained to do so by a regulated process or an agreement with government that they will over time move away from the use of line at HV and EHV. This means that they do not regularly compare the cost of cable against line at the installed or lifetime cost levels. As a result they are unaware of current cost ratios.

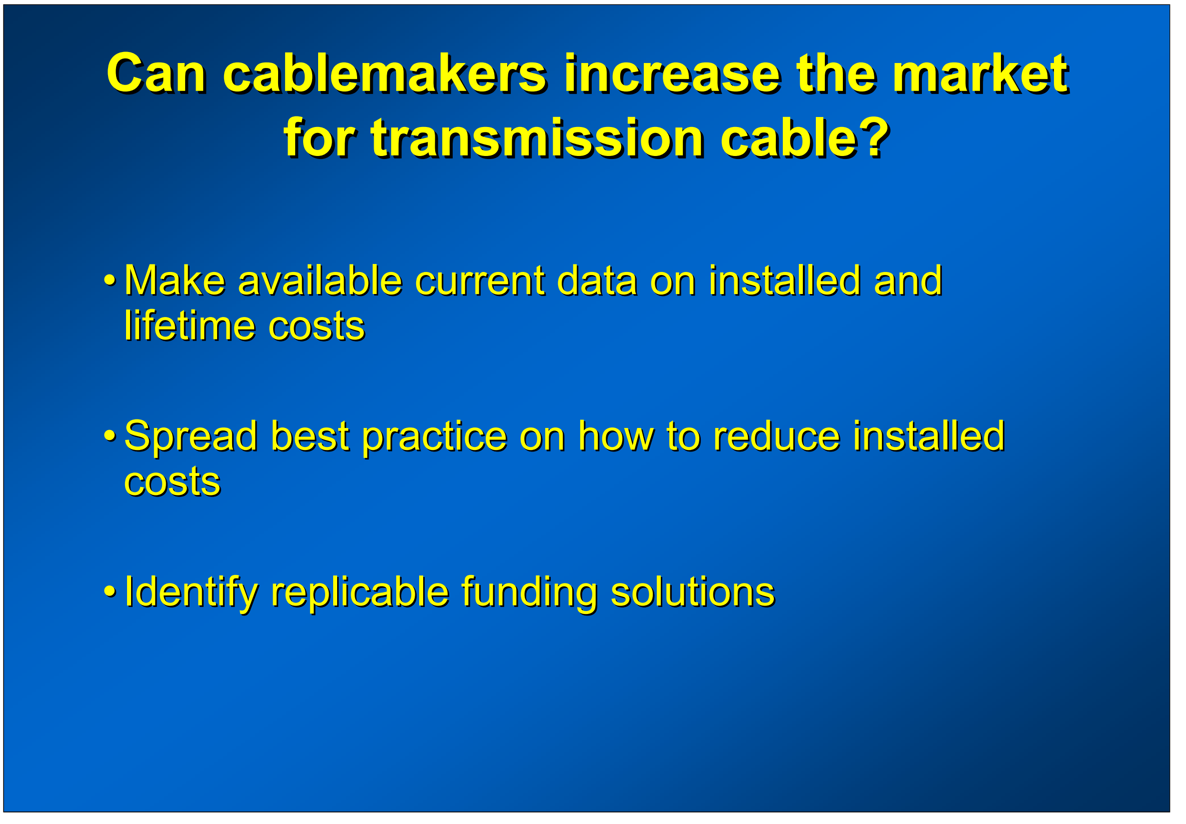
Nevertheless we detect important changes are starting to take place.



Utilities and TSOs change gradually, but we conclude they are now undergoing change in areas crucial to cable makers.

The changes illustrated on this slide are taking place as a result of regulation and executives taking up positions at board and senior management levels with experience from outside the electricity sector – and hence no strong feelings one way or the other for line and cable. Some of these executives see cable as the technology of the future for high voltage.

The “bottom line” is that the market environment is now starting to be more favourable to cable at kV levels of 50 kV upwards.



So, finally, can cablemakers increase the market for transmission cable? We don't have a definite answer to that.

Let me give you that answer at two different levels –

1. Are there obvious activities which cablemakers could pursue which would grow the market?
2. Have other industry sectors been successful in growing their markets by taking collective action?

There are obvious opportunities to facilitate growth. We were surprised at the lack of reliable and credible cost data – frankly at the ignorance of TSOs in this area.

There is no mechanism for spreading the good news on the reduced installation and operating costs.

Thirdly, in some countries, innovative funding mechanisms are being used which enable the TSOs and utilities to choose cable on a basis which provides them with just as good a return on it as if they had chosen line.

Other sectors <u>do</u> have a record of success. Just looking at your own supplier industries the aluminium and copper sectors have an impressive record of positively influencing and growing their end user markets through collective programmes.

So to sum up the conclusions of this investigation:

- Cost ratios have come down significantly since the mid 1990’s at the key kV level of 110 kV to a level of around 1 – where TSOs should start at least to consider cable across a much wider range of projects than currently is the case.
- TSOs are not doing this currently unless the project comes under the jurisdiction of a regulated consultation process.
- Network policy amongst TSOs worldwide is moving slowly towards more awareness of using cable at high voltage levels but it is patchy. There are only a very few TSOs with an announced commitment to cable at these voltages.
- The shift towards TSOs accepting cable at these kV levels on a much wider basis could be encouraged and accelerated if cable makers were to start proactively to put the case for cable at high voltage.
- The prize could potentially be 50,000 k circuit kilometres of additional high voltage cable in the countries we have investigated over, say, a 10 year period (based on cable penetration of 10% as compared to current levels of 5%).