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Chapter 8: Analysis of Challenges to Nuclear Power Plant Safety Management: Finland, Sweden, and the European Context

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ABSTRACT

This chapter provides an overview of the most important safety management challenges within the European nuclear power industry and explores the special characteristics of Finland and Sweden in the European context. The data were gathered as part of the LearnSafe project[1] in 2002 and the SAFIR research programme[2] in 2003-2004. The results suggest, in general, that challenges relative to human resource management and organizational climate and culture are regarded as most important in Europe. The major differences between Finland and Sweden relate to organizational climate and culture-related issues, which are more emphasised in Finland, and to the perceived importance of economic pressures and other external factors, which receive more attention in Sweden. The paper also establishes links between the key findings of the analysis and factors characterising the performance and the operating environment of the Nordic nuclear power plants. Finally the paper gives suggestions and recommendations for further research and action in the context of safety management.

INTRODUCTION

Over the past decade managers of utilities and nuclear power plants (NPPs) have been confronted with a number of new challenges. Especially ageing plants and equipment (OECD/NEA 2000), the ongoing generation turnover (OECD/NEA 2001), and the deregulation of the electricity market (Bier et al. 2001) have been shaping the scope and nature of managerial concerns and responsibilities. The managers have responded in different ways. For example, outsourcing and the use of subcontractors in general have accelerated as a means of optimising the use of resources and introducing cost savings (Kettunen et al. 2004a).

The nuclear power industry as a whole makes a rather unique and consistent community. One factor connecting utilities, licensees, contractors, regulators as well as researchers world-wide is the recognition of the paramount importance of safety. In practice this means that most technical modifications as well as major organisational change initiatives are usually subjected to a rigorous safety analysis before their implementation is approved, and that the relative weight of safety clearly exceeds that of other matters – such as sole technical or economic considerations – in the decision-making process.

[1] Learning Organisations for Nuclear Safety 2001 – 2004. The project was co-ordinated by VTT and received funding from the 5th Euratom Framework Programme with the contract number FIKS-CT-2001-00162.

[2] SAFIR 2003 – 2006 is the Finnish public research programme on nuclear power plant safety. The programme is managed by VTT under the administration of the Ministry of Trade and Industry (KTM). The main funding sources are State Nuclear Waste Management Fund (VYR) and VTT.

There are, however, examples of events in which strive for short-term economic advantage as well as sheer managerial indifference have gained the upper hand. The criticality accident at JCO nuclear fuel conversion facility in 1999 is a relatively recent, well-documented and extreme case of such behaviour (see e.g. Furuta et al. 2000). The case demonstrated how important it is to identify the critical functions to be managed and to establish appropriate goals, policies and priorities to support the management of potentially conflicting demands and expectations.

Despite the global nature of the industry there are country-specific differences in the status of nuclear power. The size and age of the industry, the nuclear share of electricity generation, and support among various interest groups of the society vary from country to another. For example, while the German federal government persuaded German utilities to commit themselves to a gradual phase out nuclear power (OECD/NEA 2004), the Finnish government as well as the Finnish parliament have both supported the application of a Finnish power company TVO to build new nuclear capacity (www.tvo.fi). Especially in Europe the differences are in this respect large and give raise to an assumption that the NPP managers' problem space may include a particular country-specific element.

In trying to understand managerial challenges several authors have cultivated the concept of competing values that have to be balanced. Some authors speak about the need to manage ambiguity and paradox (Peters & Waterman 1982), or establish balance between chaos and order (Waldrop 1992), while some emphasise the need to identify and separate between important tensions (Cameron & Quinn 1999). The view that organisations position themselves differently in response to their inherent needs has also been integrated into cultural research (Hofstede 1997, Trompenaars & Hampden-Turner 1998). Quinn (1988) has written about managers' need to fulfil many competing expectations and to handle contradictory demands, such as simultaneous requests for flexibility and control. Within the context of nuclear power, for example Rollenhagen (2002) and Wahlström and Rollenhagen (2004) have stressed the importance of securing a proper allocation of management attention over a number of competing focus areas or issue domains.

The question we want to address is as follows: what are those challenges that currently compete for European NPP managers' attention? The main objective of this chapter is to present an overview of the most important management challenges within the European nuclear power industry in the context of safety, to characterise those challenges with respect to generic demands of managerial work, and to highlight major similarities and differences between five European countries. The countries involved in the study are Finland, Sweden, Germany, Spain, and the United Kingdom. A second objective is to describe the situation in Finland and Sweden in more detail and to explore how the managers of Nordic nuclear power plants perceive and emphasise particular problems areas. In addition, the chapter aims to establish links between the key findings of the analysis and factors characterising the performance and the operating environment of the participating Nordic NPPs. Finally the study gives some suggestions and recommendations for further research and action.

METHODS

The major part of the data utilised in this study was collected as part of the LearnSafe project in 2002. The data were generated in response to the question "What are the perceived emerging challenges in the management of nuclear power plants in the context of safety?" using Metaplan sessions and semi-structured interviews.

Metaplan sessions were designed to create an opportunity for the identification and grouping of challenges. During each Metaplan session participants were asked to individually identify and write down on separate sheets of paper four to five key challenges (statements) in response to the research question. The challenges were then collected, attached on the wall of the meeting room, arranged into larger thematic groups by the participants, and weighted within each group on the basis of their perceived relative importance. Metaplan is an active method of data collection during which the researcher acts as a moderator of the process, guides participants through the discussion and documents the results (see also www.metaplan.com for additional information on the method).

A total of 15 Metaplan sessions were conducted with senior and second-in-line (mid-level) NPP managers, of which 14 sessions were held at eight NPPs in five European countries. Usually two Metaplan sessions were held at each plant: one for senior and another for mid-level managers (due to practical reasons there were two exceptions). One additional session was held at the World Association of Nuclear Operators (WANO) in Paris. All sessions were organised by the local LearnSafe partner and carried out using the local language. Statements were afterwards when necessary translated into English by the LearnSafe research team. The organisations involved in the study are listed in Table 1. A more detailed description of the four Nordic NPPs is given in Table 2.

Table 1. Organisations involved in the study.

Organisation	Type of organisation	Country	Data acquisition method
Teollisuuden Voima Oy	Licensee	Finland	1 Metaplan session + interviews
Pohjolan Voima Oy	Utility company	Finland	Interview
Forsmarks Kraftgrupp AB	Licensee	Sweden	2 Metaplan sessions
Ringhals AB	Licensee	Sweden	2 Metaplan sessions
OKG AB	Licensee	Sweden	2 Metaplan sessions
Sydkraft AB	Utility company	Sweden	Interview
Vattenfall AB	Utility company	Sweden	Interview
Grafenrheinfeld NPP (E.ON)	Licensee	Germany	1 Metaplan session
Almaraz NPP	Licensee	Spain	2 Metaplan sessions
Cofrentes NPP	Licensee	Spain	2 Metaplan sessions
UNESA	Utility company	Spain	Interview
Oldbury NPP (BNFL)	Licensee	UK	2 Metaplan sessions
BNFL plc	Utility company	UK	Interview
WANO	International organisation	France	1 Metaplan sessions

Table 2. Details of the four Nordic nuclear power plants involved in the study[3].

Licensee	NPP	Number of units	Present combined effect	Reactors to commercial operation
Teollisuuden Voima Oy (TVO)	Olkiluoto	2	1700 MWe	1978, 1980
Forsmarks Kraftgrupp AB (FKA)	Forsmark	3	3200 MWe	1980, 1981, 1985
Ringhals AB	Ringhals Barsebäck	4 + 1	4300 MWe	1975, 1976, 1981, 1983 Barsebäck 2: 1977
OKG AB	Oskarshamn	3	2300 MWe	1972, 1975, 1985

Semi-structured interviews were used to gather data from ten top utility managers representing

[3] Note that the figures of Ringhals AB include the second reactor of Barsebäck NPP that was operated by Barsebäck Kraft AB, a wholly owned subsidiary of Ringhals AB. The representatives of Barsebäck NPP took part in the Metaplan sessions held at Ringhals. Note that Barsebäck's second reactor was shut down in May 2005.

Pohjolan Voima Oy (Finland), Sydkraft AB (Sweden), Vattenfall AB (Sweden), UNESA (Spain), and BNFL plc (UK). Prior to analysis, data from the interview transcripts were reduced to short summary statements of perceived challenges. Those summary statements were then translated into English and integrated with the statements generated in the Metaplan sessions. The combined number of statements was 593 and those statements were analysed further. Note that the sole Nordic NPP not included in the study was Loviisa NPP (2 X PWR, 1000 MWe). Loviisa power plant is owned by Fortum Oyj.

The data analysis was conducted in four phases using a number of complementary quantitative and qualitative methods. *Phase 1* started with a brainstorming session and definition of a new classification model. The original groups of challenges formulated as part of the Metaplan sessions were heterogeneous, making comparisons between particular plants and countries difficult. Therefore the statements were reclassified using one common model.

The new model was developed by the researchers during the LearnSafe project and it included the following dimensions: (1) Economic and financial, (2) Workforce and competence, (3) Technology, (4) Systems and procedures, and (5) Environment. These dimensions were assumed to cover the major general issue domains of a NPP manager's job. The model can be seen as a modified version of earlier characterisations of factors influencing organisational learning and safety (Baumont et al. 2000, p. 32) and areas of management decision-making (Rollenhagen 2002) in the context of nuclear power. The model is presented in Figure 1.

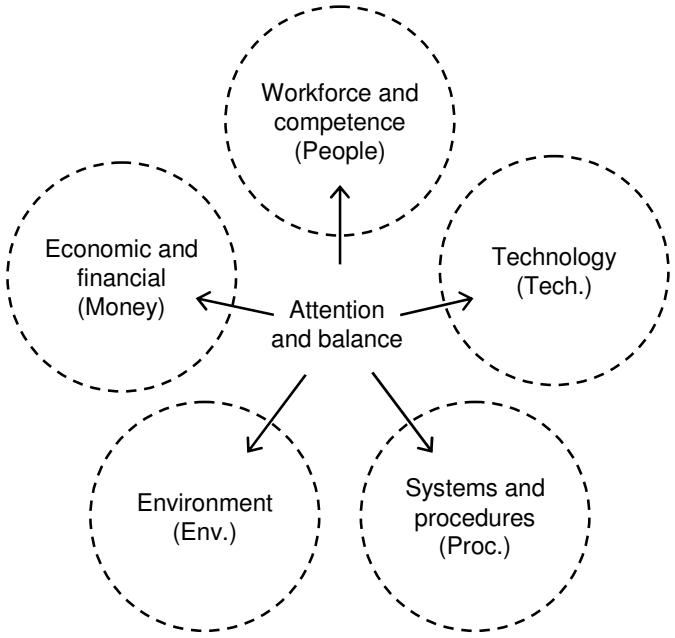

Figure 1. The generic classification model used for the coding of statements.

The five dimensions of the classification model were interpreted as *fuzzy sets*. The use of fuzzy sets can be motivated by the fact that the statements given by the managers in the Metaplan sessions and interviews were representations of their perceptions of difficult challenges facing the participating NPPs. Such statements often relate to each other as well as to various issues domains in different ways and do not therefore easily fit into mutually exclusive categories (a generic problem pertaining to the use of content-driven qualitative analysis methods). By using fuzzy sets particular challenges could be placed on one or several categories at the same time with different weights or degrees of membership. The resulting *n*-dimensional data space (in this instance $n = 5$) also allowed the use of quantitative clustering

techniques as will be explained below. For a good introduction to fuzzy sets and fuzzy logic, see e.g. Kantrowitz et al. (1996).

In *phase 2* the identified challenges were classified. The classifications were performed independently by three researchers representing three different research organisations (VTT Technical Research Centre of Finland, Lancaster University Management School in the UK, and Technical University of Berlin in Germany). The identified challenges were presented in random order, and all references to particular countries, plants and sessions were concealed from the researchers. The researchers were requested to classify the challenges with respect to the dimensions of the common classification model on the basis of their (assessed) degree of membership using a scale of 0 to 100, 0 denoting no membership and 100 very strong membership. Therefore each researcher assigned each challenge with an array of five integers.

In *phase 3* the classified statements were analysed. The classification data was combined and the *average values* of assigned degrees of membership were subjected to a series of cluster analyses. Cluster analysis was regarded as an efficient way of structuring the data (consisting of data points in the 5-dimensional data space). A hierarchical cluster analysis was conducted to determine the optimal number of clusters (see Hair et al. 1998). On the basis of the clustering (agglomeration) coefficient a nine-cluster solution was selected. K-means cluster procedure was used to create nine clusters. These nine new clusters were named by emphasising challenges located close to the cluster centres. The clustering solution was illustrated by means of multidimensional scaling (ALSCAL) and the Euclidean distance model. Associations between the clusters and the selected background variables of Country, Organisation and Management level were studied by means of cross-tabulation and Chi-square tests. The statistical tests were conducted using SPSS.

In *phase 4* data from the Swedish and Finnish NPPs were subjected to further analyses for the purpose of assessing the results of the statistical cluster analysis and identifying the country and plant-specific similarities and differences on a more detailed level. The phase was started with a review of the plant-specific results. Associations between the clusters and the four Nordic plants were studied by means of cross-tabulation and a Chi-square test (which was conducted using Excel). As part of the analysis the original groups of challenges were also contrasted with the statistical 9-cluster solution. In addition, the Finnish and Swedish data in each cluster were compared with each other on the level of individual statements. Moreover, a range of other materials from other research projects and public domains were reviewed and utilised to the appropriate extent. In this way we elaborated our understanding of the operating environment of the four Nordic NPPs and the possible (causal) relationships between selected environmental factors and the identified management challenges.

It must be emphasised here that there is a significant difference between the original groups of challenges concluded in the Metaplan sessions and the 9-cluster solution based on the classification of statements and subsequent statistical analyses. The naming of original groups illustrates how managers categorise plant-specific challenges into larger thematic entities, while the 9-cluster solution provides an overall structure for all 593 classified statements. Since the researchers classified the statements with respect to the five dimensions of the common classification model and since the model itself was introduced by the researchers, the 9-cluster solution summarises the researchers' view of the problem space given the whole empiric dataset.

An overview of the research procedure is given in Figure 2. A brief description of the applied data acquisition methods and phases 1-3 is also provided in Kettunen et al. (2004b).

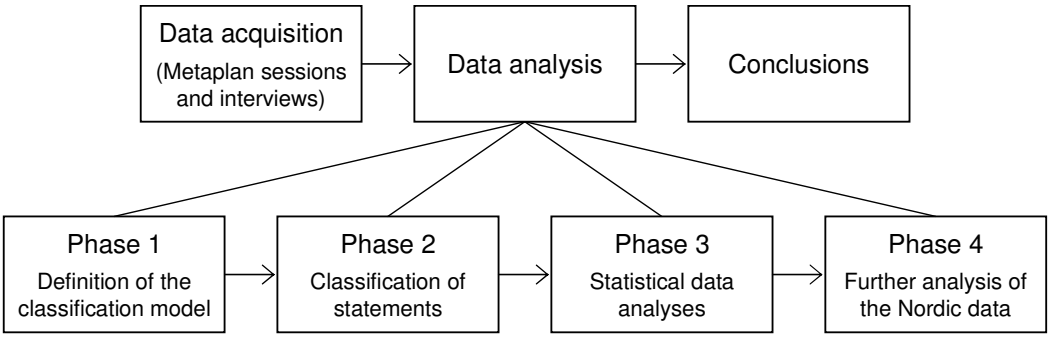

Figure 2. Overview of the research procedure.

ANALYSIS AND RESULTS

The European context

The nine new clusters proposed by the cluster analysis were named as follows: (1) Economic pressures, (2) Human resource (HR) management, (3) Nuclear know-how, (4) Rules and regulation, (5) Focus and priorities, (6) Aging, modernisation and new technologies, (7) Public confidence and trust, (8) Climate and culture, and (9) Miscellaneous (a number of challenges without a common denominator). These clusters provide an overview of today's challenges to NPP management in the context of safety in Finland, Germany, Spain, Sweden and the United Kingdom. In Table 3 the nine clusters are characterised by examples of typical challenges and statements brought out by the NPP managers and WANO officers taking part in the study. Note that some statements have been reformulated for editorial purposes.

Table 3. Characterisations of the new challenge clusters.

Cluster	**Typical challenges and statements**
Economic pressures	Competition, market conditions (taxes, subsidises, etc.), corporate pressures, cost reductions, and conflicts between costs and safety
HR management	Age distribution of personnel, early retirements, recruitment of new personnel, maintaining competencies
Nuclear know-how	Decreasing number of vendors, competency of contractors and suppliers, and the availability of external services in general
Rules and regulation	New requirements, bureaucracy and paperwork, maintaining an open communication (between the licensee and the regulator), regulatory focus (not always regarded as appropriate or effective)
Focus and priorities	Selection of correct priorities, management focus and commitment, wise use of resources, keeping procedures up to date, and managing organisational change
Ageing, mod. and new technologies	Maintaining the technical condition of the plant, ageing of plant and components, modernisations, taking new technology into use
Public confidence and trust	Societal acceptability of nuclear power, irrationality in anti-nuclear attitudes, distrust in local or regional authorities, hostility in mass media, “an accident anywhere is an accident here”
Climate and culture	Motivation and attitudes, safety culture, need to fight complacency, mental and emotional strain, organisational and human factors in general
Miscellaneous	Balance between safety – plant – people – technology, the development in the nuclear field, control of maintenance, consequences of mergers and acquisitions, decommissioning of plants, etc.

The *largest* clusters in terms of challenges included were HR management (22.3%), Climate

and culture (17.4%) and Public confidence and trust (12.8%). These three clusters were interpreted as the NPP managers' most important problem areas in the five countries.

The nine clusters are not independent of each other and have interesting connections, which can be found by taking a closer look at the cluster centres (Table 4). The columns of the table represent the nine clusters. The rows represent the five dimensions of the common classification model (see Figure 1). The numbers in cells denote the cluster centres (co-ordinates) with respect to the 5-dimensional data space. It is important to remember that the classification dimensions shall be understood as generic and context-free managerial issue domains, while the clusters identified in the study refer to specific sets of challenges in the given context.

Table 4. Co-ordinates of the nine cluster centres.

Dimension	**Cluster centres**								
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Money	83.5	41.7	37.9	13.8	22.9	48.9	18.2	13.2	57.4
People	23.6	95.7	61.6	23.1	39.9	10.4	17.1	87.2	55.0
Tech.	16.7	14.4	17.9	20.3	19.2	91.4	19.7	10.0	60.9
Proc.	47.4	48.5	43.5	78.0	76.0	43.1	30.1	53.4	56.6
Env.	66.0	42.7	79.8	84.8	29.7	19.9	90.2	17.3	43.8

Table 4 shows how Workforce and competence-related issues (People) seem to break up into three main clusters: HR management (cluster 2), Nuclear know-how (cluster 3), and Climate and culture (cluster 8), of which the first has to do with the challenge of maintaining a sufficient level of competence at the plant, the second refers to the availability and quality of external services, and the third includes motivational challenges and related organisational factors. In a corresponding way challenges linked to Systems and procedures (Proc.) appear to break up in several clusters but especially into Rules and regulation (cluster 4), Focus and priorities (cluster 5), and Climate and culture (cluster 8).

The table also illustrates how important issue domain Environment (Env.) is in the context of nuclear power; four clusters are strongly and two others moderately related to the operating environment of NPPs. On the other hand, Technology (Tech.) seems to be a rather distinctive area with strong links only to two challenge clusters: Aging, modernisation and new technologies (cluster 6) and Miscellaneous (cluster 9). It is interesting to see, however, that challenges relative to Aging, modernisation and new technologies are also moderately connected to financial issues as well as to systems and procedures.

In general, Workforce and competence, Systems and procedures and Environment emerge as dominant managerial issue domains in our analysis: most clusters score high on those dimensions, including the three biggest challenge clusters.

The mutual interconnections between the nine clusters were also studied by means of multidimensional scaling. The analysis was conducted for the distances between the nine cluster centres using SPSS (ALSCAL). The stress factor (badness-of-fit measure) was 0.0567 (moderate/ good) with 10 iterations. The results of the analysis are shown in Figure 3. Note that dimensions 1 and 2 have not been given any particular interpretations.

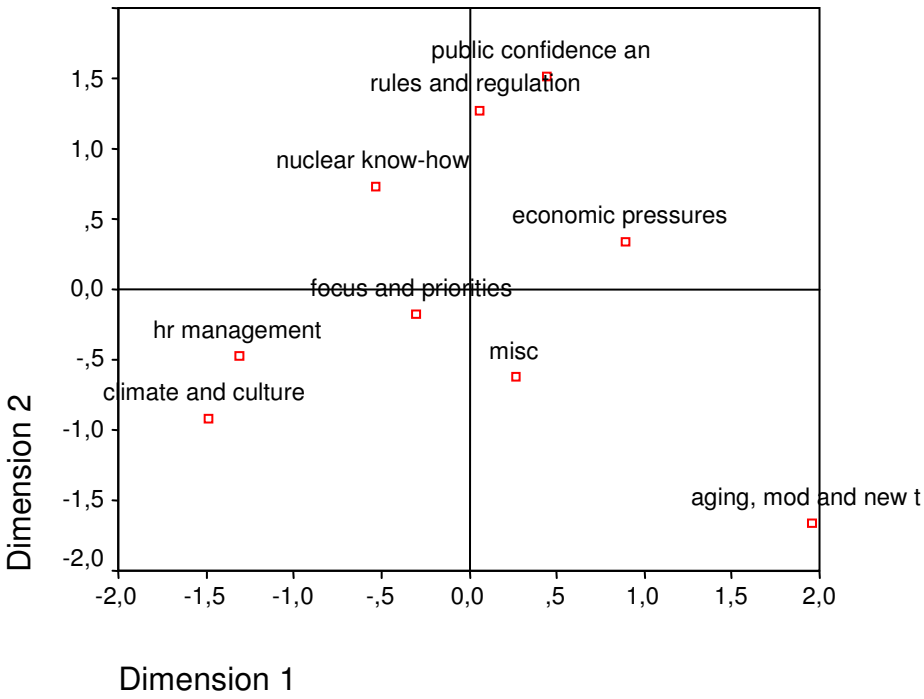

Figure 3. Euclidean distance model of the 9-cluster solution.

In Figure 3 the relative distances between the points on the plane correspond (approximately) to the distances between the cluster centres in the 5-dimensional data space. In this particular case spatial proximity in the Euclidean distance model may be interpreted to represent thematic similarity. Therefore the model suggests, as was expected, that challenges relating to HR management and Climate and culture are qualitatively close to each other. Those challenges are strongly related to workforce and competence-related issues, moderately to management systems and procedures and only slightly or not at all to technology. If a particular challenge also relates to financial matters and environment, we are presumably talking about HR management, otherwise about Climate and culture (see also Table 4).

Perhaps surprisingly, challenges relating to Rules and regulation and Public confidence and trust appear to be closely related, too. There is, however, a common denominator between these two clusters explaining the results: challenges in both clusters are strongly related to external pressures over which NPP managers have little or no control. The special nature of technology-related challenges is also clearly visible in the model. Focus and priorities-related challenges are in the middle, which illustrates their position in the intersection of other problem areas. The same applies, although to a lesser extent, also to Economic pressures.

The interesting question was of course as follows: how do the five countries covered in this study differ from each other? The cross-tabulation of the data with respect to Cluster and Country is shown in Table 5.

The first look at the table reveals that there are many similarities between the five countries. For example, challenges relating to either HR management or Climate and culture were generally emphasised in all countries (the international group being a clear exception), whereas Rules and regulation-related issues were not. In all five countries the largest challenge cluster was either HR management or Climate and culture, or they shared the top position as in Finland. However, the relative importance of Economic pressures was perceived differently in different countries. In Finland financial matters were regarded as insignificant

(at least from the safety point of view)[4], while in German and Sweden, as well as amongst the representatives of the international group, their relative importance was at least moderate. And in Sweden Climate and culture-related challenges were far less emphasised than in other countries.

Table 5. Cross-tabulation of Cluster and Country (% within Country)[5].

Challenge clusters	**Fin**	**Swe**	**Ger**	**Sp**	**UK**	**Int**	**All**
Economic pressures	0.0	12.2	15.8	11.2	3.6	18.8	10.3
HR management	21.4	28.9	18.4	18.7	26.2	8.3	22.3
Nuclear know-how	5.4	10.6	10.5	8.0	3.6	4.2	7.8
Rules and regulation	1.8	6.1	5.3	8.0	7.1	2.1	6.1
Focus and priorities	16.1	10.6	7.9	3.2	15.5	14.6	9.6
Ageing, mod. & new tech.	17.9	9.4	13.2	3.2	11.9	8.3	8.8
Public confidence and trust	10.7	10.6	5.3	20.9	1.2	18.8	12.8
Climate and culture	21.4	8.3	15.8	23.5	27.4	6.3	17.4
Miscellaneous	5.4	3.3	7.9	3.2	3.6	18.8	5.1
Total (%)	100.1	100.0	100.1	99.9	100.1	100.2	100.2
Total (*n*)	*56*	*180*	*38*	*187*	*84*	*48*	*593*

The Chi-square test conducted for the data indicated that Cluster and Country were significantly related ($\chi^2 = 127.38$; df = 40; $p < 0.001$). This suggests that despite obvious similarities different challenges tend to be emphasised in different countries. Note, that Table 5 contains the percentages to facilitate comparisons between countries.

In a similar way a comparison was also made between different plants (Organisation) and manager groups (Management level). The Chi-square tests indicated that while Cluster and Organisation were significantly related ($\chi^2 = 181.45$; df = 88; $p < 0.001$)[6], Cluster and Management level were not ($\chi^2 = 24.18$; df = 16; $p \approx 0.086$). These findings suggest that different challenges are emphasised in different organisations, while managers appear to worry about the same things irrespective of their relative rank (top, senior or middle). In the former case notable differences were also identified within single countries, e.g. between two plants in the same country. In the latter case there were only modest (and statistically insignificant) differences in relation to Economic pressures, Focus and priorities, and Public confidence and trust. As was expected, higher rank was related to a greater emphasis on economic issues, while operative (senior and mid-level) managers were more concerned about maintaining a proper focus. Perhaps surprisingly, the operative managers also appeared to be more concerned about the public image of the industry than their senior colleagues.

[4] The table shall be read as follows: none of the challenges identified by the representatives of Olkiluoto NPP in Finland (sample 'Fin') were placed in the 'Economic pressures' cluster in the analysis. This does not necessarily mean, however, that Finnish NPP managers face no economic challenges. The outcome of the analysis is strongly related to the coding of statements, which was conducted by researchers whose interpretation of particular statements may have been different from that of their introducers. Secondly, the international group, in which economic pressures were emphasised, also had a Finnish representation.

[5] 'Int' refers to data gathered at WANO and at a group interview of Finnish and Swedish top utility managers. Data sets 'Fin' (Finland) and 'Swe' (Sweden) contain only senior and mid-level NPP managers' views. This shall be borne in mind when comparing the data sets with each other.

[6] Note that the statements expressed by the top managers of the three Nordic utility companies (Pohjolan Voima Oy, Sydkraft AB and Vattenfall AB) were collected and also presented together. Therefore the number of Organisations in the analysis was 12 (instead 14) and the degrees of freedom 88 (instead of 104).

Finland and Sweden: Further analysis of the data

As a first step towards in analysing the views of the Nordic NPP managers we took a closer look at the plant-level data. The Nordic data consisted of 236 statements, of which 56 were of Finnish and 180 of Swedish origin. The cross-tabulation of Cluster and Organisation is presented in Table 6.

Table 6. Cross-tabulation of statements from the four participating Nordic plants with respect to Cluster and Organisation (% within Organisation).

Challenge clusters	**Fin**	**Swe**			**V(Swe)**	**V(N)**
	TVO	**FKA**	**RING**	**OKG**		
Economic pressures	0.0	8.1	19.0	9.3	0.49	0.86
HR management	21.4	29.7	28.6	27.9	0.03	0.14
Nuclear know-how	5.4	13.5	9.5	7.0	0.33	0.40
Rules and regulation	1.8	5.4	6.3	7.0	0.13	0.45
Focus and priorities	16.1	6.8	9.5	18.6	0.53	0.43
Ageing, mod. & new tech.	17.9	6.8	6.3	18.6	0.66	0.55
Public confidence and trust	10.7	16.2	9.5	2.3	0.74	0.59
Climate and culture	21.4	10.8	6.3	7.0	0.30	0.61
Miscellaneous	5.4	2.7	4.8	2.3	0.41	0.40
Total (%)	100.1	100.00	99.8	100.0		
Total (*n*)	*56*	*74*	*63*	*43*		

The Chi-square test conducted for the data indicated that in the *Nordic* data Cluster and Organisation were moderately related ($\chi^2 = 41.27$; df = 24; $p \approx 0.017$). This suggests that different challenges tend to be emphasised at the four Nordic plants. Note that Table 6 contains percentages to facilitate comparisons between plants. The coefficient of variation[7] (V(X)) is used to measure relative deviation within the three Swedish plants (V(Swe)) and within all four Nordic plants (V(N)) as regards the relative size of each challenge cluster.

A qualitative analysis of Table 6 suggests that there are, nevertheless, a few similarities between the four Nordic plants. First of all, HR management-related challenges, such as ageing personnel and competence management, were strongly emphasised at all plants. Especially in the three Swedish plants HR management clearly outweighed all other areas of management activity. Secondly, Nuclear know-how, which in our analysis relates to the (long-term) supply of external and industry-specific products and services, was fairly uniformly emphasised in all Nordic plants, though its relative importance was lower than that of HR management.

In case of Focus and priorities, Ageing, modernisation and new technologies and especially Public confidence and trust differences between particular plants are great. In case of these three clusters the relative deviation within the Swedish data (V(Swe)) actually exceeds that of the whole Nordic data set (V(N)). This is an interesting result, but because only one Finnish plant participated no final conclusions can be drawn at this stage.

[7] The coefficient of variation is the standard deviation divided by the mean, a unitless quantity indicating the variability around the mean in relation to the size of the mean.

The most notable difference between TVO and the Swedish NPPs relates to the perceived importance of Climate and culture-related challenges. So, there seems to be a clear country-related difference. This finding raises further questions about the underlying causes. Another similar area is Rules and regulation, which was smaller in TVO than in the three Swedish plants. When it comes to Economic pressures, financial matters appeared to weigh heavy only for Swedish NPP managers. On the other hand, the three Swedish plants varied in this respect (Table 6).

The results so far seem to suggest that with a few exceptions, country alone cannot explain differences between the three Swedish plants and the Finnish plant.

The second step in analysing how the Nordic NPP managers make sense of their operating environment involved extracting the *original* groups of challenges from the primary data. One Metaplan session and the interview held at the Finnish plant had resulted in 56 statements in nine groups, while the six sessions held at the three Swedish plants produced 180 statements in 33 groups. The original groups of challenges are listed in Table 7. All groups that explicitly refer to workforce, personnel, competence, culture, climate and/ or attitudes have been underlined.

Table 7. Original groups of challenges at four Nordic NPPs.

Plant	**Management level**	
	Senior	**Middle**
Olkiluoto (TVO, Finland)	Plant condition Personnel A new plant Society	The technical condition of the plant Personnel / attitudes, alertness, etc. Personnel / know-how Regulatory role Procedures and practices
Forsmark (FKA, Sweden)	Competency support in the nuclear field Profitability Company culture Confidence	Competency Skilful authority Economy Organisation Technology Politics
Ringhals (RING, Sweden)	Competency Requirements Maintaining technical preconditions Economy Management	Generation change Competency Consequences of change Risk of imbalance between econ. & safety Changed (technical) preconditions Attitudes, politics, policy Modernisation General issues
Oskarshamn (OKG, Sweden)	From old to new technology Competence and competence management Analysis Safety culture Misc	Competence Management /control Rules and demands Plant life management Economy and safety

Table 7 shows that personnel and competence-related issues were present in the primary data and mentioned by both senior and mid-level managers in both countries in all four plants. Various technical challenges and concerns about the regulator's views and activities were explicitly addressed at each plant. On the other hand, certain types of groups were formed only by the Swedish NPP managers. Economy, (the imbalance between) economy and safety, as well as company and safety culture were examples of such groups. So there seems to be a clear difference between the Finnish plant and the Swedish plants concerning the original

grouping solutions. The problem was, however, that the picture emerging from Table 7 seemed to be contradictory to the finding that climate and culture-related challenges are more common in Finland than in Sweden (see Tables 5 and 6).

To solve the puzzle we went through all the 236 individual statements for the purpose of establishing the relation between the original groups of challenges and the new clusters. Then, it became apparent that the Finnish NPP managers had identified many HR management as well as Climate and culture-related challenges during the Metaplan sessions, but without explicitly referring to the concepts of 'climate' or 'culture' when grouping them into thematic entities. This explains the seemingly contradictory results in terms of the Finnish data.

A review of the Swedish data yielded interesting results, too. Our first discovery was that seven out of the 15 statements that were mapped to Climate and culture had originally been placed under the title 'Organisation'. Moreover, statements in other groups that may be regarded as thematically related, such as 'Risk of imbalance between economy and safety' and 'Economy and safety', had not been interpreted to be much people-related by the researcher who carried out the coding. Therefore, these statements were sorted into other clusters in the analysis[8]. However, competence-related groups, including 'Generation change', were mostly mapped into HR management, as expected.

The review of the Swedish data did not provide any corresponding simple explanation for the divergent results. However, some coding differences seem to explain a considerable part of the divergence. HR management-related challenges were well represented in the Swedish data. In conclusion, the results of the reanalysis appear to be in line with the results of the statistical cluster analysis, although the fit is far from perfect.

After the review of the original grouping solutions all statements derived from the four Nordic NPPs were sorted within the *new* clusters according to their relative importance, as determined by the participating managers, and analysed on the level of individual statements with respect to their content and main focus areas. The key findings are summarised below.

(1) *Economic pressures*. The Finnish NPP managers did not regard this area as important in the context of safety. The Swedish NPP managers, however, were clearly concerned about the conflict between economy and safety. In particular, they appeared to be worried about the owners' (i.e. top utility managers') interest in and long-term commitment to the industry.

(2) *HR management*. Finnish and Swedish NPP managers shared similar concerns. The challenges imposed by the ongoing generation change and the need to transfer the necessary skills and knowledge to the younger generation dominated their thoughts in this area.

(3) *Nuclear know-how*. Both Finnish and Swedish NPP managers appeared to share the same concern: How to secure an adequate supply of vendors and external services in the future? A reference to business trends was made by one Swedish manager, having supposedly to do with the perceived risk of applying modern management models in the context of nuclear power. The Finnish NPP managers did not refer to this particular issue.

[8] The co-ordinates of the centres of the nine new clusters are given in Table 4. Climate and culture (cluster 8) is strongly related to People, moderately to Systems and procedures, and only slightly to three other dimensions of the common classification model. Therefore statements with an explicit reference to financial matters are likely to have been mapped into other clusters.

(4) *Rules and regulation*. The Finnish NPP managers did not regard this area as important. The Swedish NPP managers expressed their concern about inadequate and changing regulatory demands, which in their opinion sometimes drifted their resources away from more important things. They were also criticising excessive formalism and bureaucracy for the same reason.

(5) *Focus and priorities*. The challenge of keeping focus on the essential things was emphasised by both Finnish and Swedish NPP managers. The Finnish managers paid also attention to the need to develop procedures and support systems in response to the demands of the changing working life, while their Swedish colleagues brought out the paradox of success and the risk of focusing on only short-term issues. In general, the challenges identified by the Finnish managers appeared to be more specific and concrete, while the concerns referred to by the Swedish managers were typically of more generic nature.

(6) *Ageing, modernisation and new technologies*. Ageing plants and components, modernisation of plant systems and introduction of new technology were explicitly referred to as challenging problem areas by both Finnish and Swedish NPP managers. Those challenges have to do with the overall requirement of maintaining the 'technical condition' of the plant. There were no significant thematic differences between the two countries in this area.

(7) *Public confidence and trust*. The Finnish managers were mostly worried about the regulator's position on validation and licensing-related issues, while the Swedish managers also referred to a number of other external interest groups, including the general public, politicians, suppliers and owners. In consequence, as regards the content of individual statements there was a clear difference between the two countries.

(8) *Climate and culture*. Motivational issues received more attention in Finland than in Sweden. Otherwise the managers of both countries addressed similar type of safety-related topics, such alertness, attitudes, open and questioning climate, and safety consciousness.

The results suggest that the overall picture is complex and that one should not draw far reaching conclusions of the situation without paying careful attention to the multiplicity of the data and alternative explaining models.

DISCUSSION

The European context: HR management challenges rule

The present study has given some interesting findings relevant for the European nuclear industry in general and for Nordic safety management in particular. Overall, it was found that human resource management and organisational climate and culture are the two most challenging areas in the context of safety for NPP managers across Europe. Age distribution of personnel, early retirements, recruitment of new personnel, and maintaining competencies are examples of concurrent HR management-related concerns. Maintaining personnel motivation, building a proper safety culture and fighting complacency, and managing mental and emotional strain are examples challenges that were grouped under the term climate and culture in this study. It may therefore be concluded that organisational and human factors in general constitute a very significant portion of the NPP manager's 'problem space' in Europe.

These findings are well in line with the results and projections of many earlier studies. For example, the study conducted by the Committee for Technical and Economic Studies on Nuclear Energy Development and Fuel Cycle of the OECD Nuclear Energy Agency in 1998 revealed that the number of students graduating at bachelor's and master's level in nuclear science and engineering has been decreasing since 1990 in the OECD member countries (OECD/NEA 2001). This in turn translates into recruitment challenges and greater reliance on the licensees' in-house training programmes. When it comes to climate and culture, and especially personnel motivation, we should not underestimate the potential effects of deregulation and increasing competition. For example, the Nuclear Installations Inspectorate (NII) has identified signs of low morale among the regular employees of UK nuclear sites that have been subjected to various change and development projects to boost efficiency. Since these projects often result in downsizing and an increased use of external contractors, they also create uncertainty about future employment prospects (Bier et al. 2001, HSE).

One interesting finding of the study was that the perceived relative importance of various issue domains is not related to management level, i.e. the manager's formal position in the utility or plant organisation. This may stem from the fact that until recently the top and senior managers usually are recruited internally within the plant organisation, or at least from within the nuclear power industry.

There were, however, differences also across countries. This seems natural given that the nuclear power programmes of the five European countries are also different in many other ways. But establishing a logical connection between our findings and selected circumstantial factors of the participating countries proved to be a challenging exercise.

For example, personnel-related challenges were given a great deal of attention in Finland despite the fact that the country's nuclear power industry had a steady footing and progressive future plans. At the time of data acquisition in the spring of 2002 the Council of State had already made a positive decision in principle to support TVO's application for a new nuclear power unit (see e.g. www.tvo.fi). Therefore, one could have expected that the challenges of managing the inevitable generation turnover and maintaining good motivation of personnel, as demanding these tasks may be in practice, should have received far less emphasis in Finland than in any other of the four participating countries. Secondly, public confidence and trust together with rules and regulation emerged as least challenging areas of management activity in Germany, although it is a well known fact that lacking public support for the use of nuclear power and amounting political pressures forced the German utilities to conclude a contract with the government on a gradual phasing-out of operating nuclear power plants (OECD/NEA 2004). Moreover, while the British NPP managers together with their Finnish colleagues ranked economic pressures low, the British utility involved in the study has nevertheless been operating unprofitably since the late 1990s and shutting down its elder plants due to increasing operation and maintenance costs and generally unfavourable economic prospects of nuclear power-based electricity generation (BNFL 2003, OECD/NEA 2004).

The above-listed examples clearly show that the relationships between the identified management challenges and various political and economic factors are not straightforward. The lesson learned is that the findings of the analysis shall not be mechanistically linked to, or derived from, any particular simplistic view an societal (e.g. political) processes that have taken place or are underway in the countries covered in this study. The results thus suggest that the NPP managers' problem space is shaped by a number of interacting factors, of which many originate from within the plant organisation. Nevertheless, there are common denominators, such as HR management for example, that conjoin NPP managers in different

countries and different plants and which therefore lay a natural foundation for the exchange of ideas, experiences and good practices. Technology is another obvious field for co-operation.

Finland and Sweden: A mixed picture

Ambiguity is perhaps the right word to describe the nature of our findings with regard to the further analysis of the Nordic data. One thing is for sure: HR management-related challenges receive a lot of attention among both Finnish and Swedish NPP managers. In this respect the two Nordic countries are no different from the three other European countries covered in this study. However, presenting a comprehensive, yet concise, overview of the situation in the two Nordic countries is a difficult task. For example, while some of the challenge clusters were differently emphasised in the two countries, they still were similar in terms of their nature and content (e.g. Climate and culture). On the other hand, there were clusters with the same relative importance in both countries, but different contents and focus (e.g. Public confidence and trust). And in general, the differences between particular plants were many times surprisingly large.

A logical starting-point for the search for explaining factors was to take a closer look at the performance data of the four Nordic plants. We first paid attention to load factors, i.e. the ratio between the actual and maximal electrical output of a plant over a specified period of time. The analysis revealed that between 1996 and 2003 the average load factors of the three Swedish NPPs have remained well below those of TVO and that they have also been subject to strong fluctuation. In short, TVO outperforms the three Swedish plants with a wide margin (Figure 4).

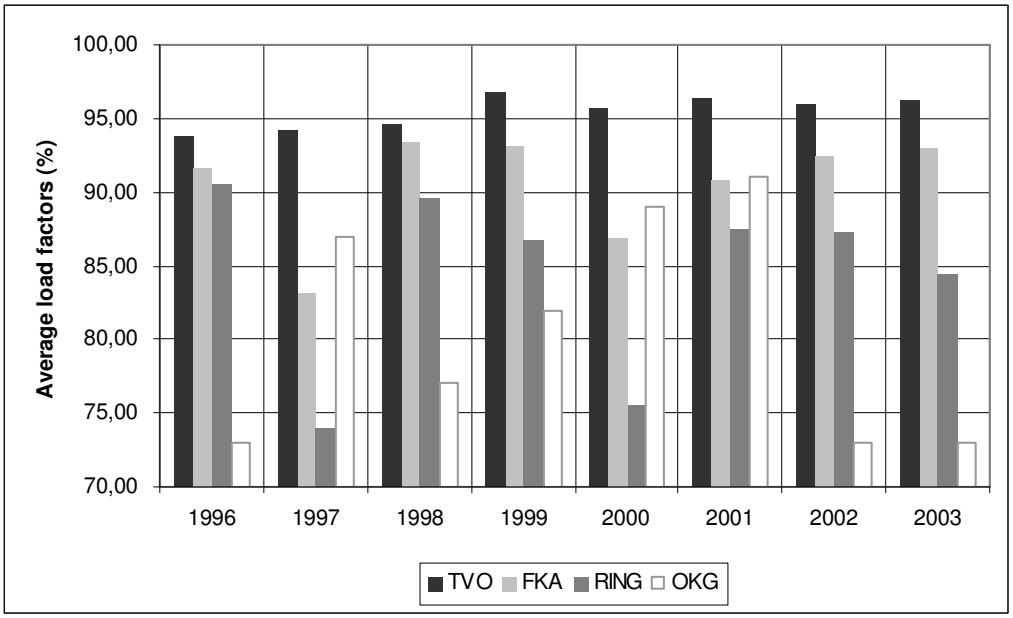

Figure 4. Average load factors (%) of four Nordic nuclear power plants in 1996-2003. Sources: Teollisuuden Voima (TVO), Forsmarks Kraftgrupp (FKA), Ringhals and OKG.

Operating age could in principle partly explain the difference between the Finnish and Swedish plants. Oskarshamn 1 and 2 as well as Ringhals 1 and 2 were brought to service before TVO started generation. Forsmark 1 and 2, however, are of similar design and same age than their Finnish sister reactors Olkiluoto 1 and 2 of TVO (see table 2). Moreover, also TVO has implemented ambitious modifications during the same period of time, including a

large modernisation programme that was carried out during the second half of the 1990s. Still its annual load factors have remained at excellent levels.

The picture gets more complicated when the average load factors are contrasted with additional plant performance data, such as reactor and turbine scrams and INES-classified operating events[9]. In 1996-1997 TVO had more scrams per unit than any of the three Swedish plants, and during the years 1998-1999 and 2001-2002 TVO had the second highest scrams per unit rate (KSU). Moreover, between the years 1997 and 2002 TVO had clearly more INES 1 classified events than any of the three Swedish plants with the exception of the year 2000 when TVO's performance in general was very good (STUK, SKI). In other words, TVO's load factors have remained at exceptionally high levels despite relatively frequent reactor and turbine scrams and INES-classified events[10].

The failure statistics may, however, help explaining why technical challenges were actually stressed at TVO. In addition, they help explaining why the representatives of OKG emphasised this area more than their Swedish colleagues: OKG have had more scrams per unit than the two other Swedish plants for a number of years with the exception of year 2002 when FKA 'took the lead' for the first time. The findings suggest, too, that the Finnish regulator, STUK, has been rather flexible towards TVO – otherwise the situation could have been quite different with a series of regulator interventions and forced outages which would have had a significant negative impact on the plant's average load factor. No wonder that rules and regulation were generally regarded as the second least important challenge area at TVO.

A good load factor also translates into high production volumes which contribute to a steady revenue stream. Therefore the load factor may function as a key to understanding the differences in the relative importance of economic pressures between the plants, and especially between TVO, where the relative weight of this area was minimal, and Ringhals, where economic pressures were the second most important area after HR management. In terms of average load factors Ringhals lags far behind TVO. This gap, however, does not provide a satisfying explanation for the findings of the analysis, for the relationship between the annual turnover and the load factor appears to be loose. Instead, the revenue graphs appear to behave smoothly and in accordance with the development of the price of electricity.

Deregulation of the Finnish and Swedish electricity markets in 1995-1996, introduction of a joint Norwegian-Swedish power exchange, Nord Pool ASA, in 1996, as well as heavy rains in Norway in 1996-1997, which filled the country's water reservoirs and thus made the supply of hydroelectric power abundant, eventually led to the decline in the electricity prices in the Nordic interconnected grid. The declining trend continued until the end of the decade, and the prices bottomed in 2000 (Nord Pool). In consequence, the revenues declined, too, and the power companies were forced to introduce cost saving. This must have had at least a modest impact on the NPP managers' work either directly or indirectly.

Despite the existence of a common Nordic electricity market, private households as well as industry in general paid a bit more for their electricity in Finland than in Sweden between 1996 and 2001 (Energy Market Authority, Statistics Sweden, Nord Pool). This has provided the Finnish power companies, including TVO, a sort of economic advantage over their

[9] INES = the International Nuclear Event Scale, a system for the classification of operating events according to their safety significance. The scale runs from 1 (anomaly) to 7 (major accident). See also: www.iaea.org.

[10] Note that the statistics of the year 2003 have been intentionally omitted from this analysis, because the underlying Metaplan and interview data were collected in 2002.

Swedish competitors.[11] This in part may explain the results of the analysis when it comes to the perceived importance of economic pressures at the four Nordic plants: TVO has managed to pile up money to cover future – planned as well as unplanned – expenditures.

The overall situation in Scandinavia, however, started to change in 2001-2002. The price of electricity bounded ahead, and the price levels in Sweden gradually bypassed Finland in most customer segments. TVO's financial results also eroded, though supposedly due to increasing investments in the planning of the new unit. The Metaplan sessions and interviews were conducted in the midst of this economic change in 2002. It is therefore difficult to estimate to what extent and exactly how those changes are reflected in the primary data.

Overall conclusions and recommendations

The results show how the pressures from the working environment can be perceived in many different ways. Even though the focus of this study was on perceived safety-related challenges, the emerging picture of the managers' problem space encompasses a number of issues (cf. Weick 1995). In terms of the generic managerial issue domains workforce and competence, systems and procedures and environment emerged as dominant in our analysis. In terms of context-specific challenges HR management, climate and culture, and public confidence and trust were mostly emphasised. Safety cannot thus be managed independently of other goals, such as internal efficiency or public image.

Clearly the managers have to cope with and make sense of ambiguous situations and demands (cf. Weick 1995, p 93). Further, the demands extracted in this study could be interpreted as competing goals (Quinn 1988) with seemingly contradictory criteria for performance. The challenge is to pursue all the competing goals simultaneously. Given the fact that human as well as organisational decision-making processes are characterised by 'bounded rationality' and 'satisficing', as stated by March and Simon already in 1958, one may conclude that the task of balancing attention and resources in a proper way is a critical one.

Comparing the challenges across stations and countries proved that the challenges were perceived differently. Some can be attributed to genuine differences in the political climate of the five countries covered in this study. But many others seem to have more to do with the organisational (cf. Schein 1985) than national culture or circumstances. This exercise of comparing the challenges across various stations could be fruitful for the managers in clarifying their cultural biases. Nuclear community is very international and co-operates quite closely. Nevertheless, the differences in the perceived safety challenges are large. It could be hypothesised that these differences in perceptions of the working environment would be even larger in some less international industry.

The role of the regulator is also a question that needs further attention and research in the future. Regulatory practices were raised as a safety concern in a number of plants, even though the regulator is supposed to contribute to the safety of nuclear power. Still, the responsibility for safety is undivided and always resides with the licensee. This raises questions about the role of the regulator in general and methods that could be best suited for this role in particular (cf. Kirwan et al. 2002).

Future research and development work should focus on clarifying the nature of the different

[11] The four Nordic licensees involved in this study generate electricity for their shareholders at cost. Therefore all assessments on financial results are based on profits before appropriations and taxes as reported by the licensees.

challenges extracted in this study, and especially the interface and interaction between the challenges. A related topic for future research and development work concerns applied management models. Are same kind of management initiatives and methods suitable for tackling all the challenges, or does every challenge require a unique approach?

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