

Cordless Power Tools in the Nordic Countries

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Nordic co-operation

Nordic co-operation, one of the oldest and most wide-ranging regional partnerships in the world, involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Co-operation reinforces the sense of Nordic community while respecting national differences and similarities, makes it possible to uphold Nordic interests in the world at large and promotes positive relations between neighbouring peoples.

Co-operation was formalised in 1952 when *the Nordic Council* was set up as a forum for parliamentarians and governments. The Helsinki Treaty of 1962 has formed the framework for Nordic partnership ever since. The *Nordic Council of Ministers* was set up in 1971 as the formal forum for co-operation between the governments of the Nordic countries and the political leadership of the autonomous areas, i.e. the Faroe Islands, Greenland and Åland.

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Preface

This report was drafted by Jakob Maag and Susanne Skårup of COWI Consulting Planners and Engineers, Denmark, for the Nordic Council of Ministers. The study was coordinated by Anne Nielsen of the Danish Environmental Protection Agency.

The study was followed by a steering group counting the following representatives of the national environmental authorities of the Nordic countries:

- Iceland: Stefan Einarsson, Environment and Food Agency (UST)
- Finland: Klaus Pfister, Ministry of the Environment
- Norway: Morten Helle, Norwegian Environment Protection Agency (SFT)
- Sweden: Cecilia Stafsing, Swedish Environment Protection Agency (Naturvårdsverket)
- Denmark: Anne Nielsen, Danish Environment Protection Agency (Miljøstyrelsen).

The correctness of the presentation of collected data is the responsibility of the consultants.

Executive summary

The report describes the supply situation for cordless power tools in the Nordic countries and discusses the key technical factors influencing substitution of NiMH for NiCd batteries in this sector. NiMH-driven power tools are sold in large quantities today, particularly on the professional market. Several large producers of cordless power tools recommend NiMH to professionals. The report presents new data which may inform the process of defining a sustainable regulation of NiCd batteries in the European Union.

The toxic heavy metal cadmium is used in rechargeable nickel cadmium (NiCd) batteries, and is spread to the environment through, among others, treatment of waste containing the batteries that have not been sorted out. Cordless power tools currently constitute the largest single input of portable nickel-cadmium (NiCd) batteries to the society in Denmark and likely in many other European countries. While most other uses of portable NiCd batteries have been substituted today due to better performance of alternative rechargeable batteries, and probably due to introduction of a ban on NiCd batteries in earlier drafts for a new EU battery directive., NiCd's have however remained the principal power source for cordless power tools until recently. This report documents that in some of the Nordic countries the substitutes, mainly nickel-metal-hydride (NiMH) batteries, are on the verge of superseding NiCd on the markets for cordless power tools. This is a result of both regulatory pressure (NiCd tax in Sweden and Denmark) and improved technical performance of NiMH batteries for power tools. Also in Norway and Finland, which have no specific tax on NiCd batteries, NiMH-driven power tools are sold in large quantities today, particularly on the professional market, which have high demands for performance. Several large producers of cordless power tools now recommend NiMH to professionals. The report describes the supply situation for cordless power tools in the Nordic countries and discusses the key technical factors influencing substitution of NiMH for NiCd batteries in this sector. The report presents new data which may inform the process of defining a sustainable regulation of NiCd batteries in the European Union.

NiMH market shares in Nordic countries

NiMH has now gained substantial market shares both among professionals and private consumers in the Nordic countries. In 2003, the share of

NiMH in Denmark for professional tools was estimated at about 60% and it is most likely still on the rise in 2004.

As a result of technological advancements and environmental advantages NiMH was introduced in cordless power tools on the European market around 1997 as a substitute for NiCd. NiMH and Li-ion rechargeables had already at that time substituted much of the NiCd metal use in consumer electronics such as cell phones and portable computers. The higher battery capacity per recharge was an attractive feature for professionals and in the first few years, NiMH was only available in high end professional power tools. By the turn of the century, NiMH however also became economically within reach for private consumers - in Denmark and likely also in other the Nordic countries - in low price Do-It-Yourself power tools. The NiCd tax in Denmark, and likely also in Sweden, probably made the use of the currently more expensive NiMH cells feasible. The sales of these so-called No Name power tools are hard to quantify accurately, but available data indicate that No Name NiMH power tools may constitute up to about half of the Do-It-Yourself in Denmark today. Traditional well known brands of cordless power tools still mainly offer NiCd-driven tools to the Do-It-Yourself segment, except for the introduction of a Li-ion-powered cordless screwing machine in 2003.

NiMH share on Nordic markets

Data from this study, and a recent assessment in Denmark, show that NiMH has now gained substantial market shares both among professionals and private consumers in the Nordic countries. An overview of estimated market shares of NiMH-driven cordless power tools is given in table 2-1.

It is important to note a difference between the Nordic countries: Sweden and Denmark have specific taxes on NiCd batteries, including power tool batteries. This is not the case for Iceland, Finland and Norway. The Swedish and Danish markets have therefore been put under extra pressure to shift to NiMH. It is however interesting in this perspective, to observe that NiMH also have substantial market shares in Norway and Finland.

Table 1. Market shares of NiMH-driven cordless power tools in 2003/2004 in the Nordic countries

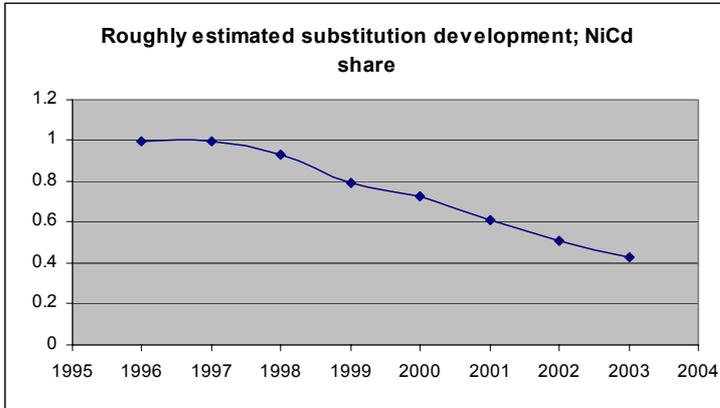
Country and product sub-category	NiMH share of market (% of number of tools sold)*1	Remarks
Denmark		
Professional power tools	60%	2003, based on a 2004 study performed in Denmark; probably larger in 2004
Do-It-Yourself	30-50%	Rough estimate from this study
Iceland		
Total market		Likely only a minor share of NiMH in 2004, based on data from this study
Finland		
Total market	30%	Estimated by TKL, Finland, 2004
Norway		
Professional power tools	50-60%	Estimated from detailed data in this study, 2004
Do-It-Yourself		Unknown, but may be substantial (perhaps near levels in Denmark or Sweden)
Sweden		
Professional power tools	90%	Estimated by LEH, Sweden, 2004
Do-It-yourself	35%	Estimated by LEH, Sweden, 2004

Note: *1 NiCd and NiMH currently dominate the market, while a third battery type, Li-ion, is expected to have a small but rising market share in the Nordic countries.

Development of NiMH share of the market

For the professional market in Denmark, an estimate for the share of NiCd batteries of the total sales of cordless power tools was formed in a recent study sponsored by the Danish EPA. The estimate was based on detailed information from individual producers. In 2003, the share of NiMH for professional tools was estimated at about 60%, and based on information from producers it was most likely still on the rise in 2004. As several of the major power tool brands are the same in all the Nordic countries, the trends may likely have been similar in the other Nordic countries. Figure 2-1 shows the progressive drop in NiCd share of the professional cordless power tools market in Denmark. The figure is based on detailed information from dominating producers represented on the Danish market.

Figure 1. NiCd share of total battery sales for professional power tools (from Maag and Hansen, 2004)



Power tools with Li-ion batteries

As a recent development, power tools with Li-ion batteries have been introduced on the market in 2003, which thereby follows the trend of other electric and electronic products in the pursuit of ever increasing effect per weight of portable equipment.

Life time capacity of NiMH

NiMH has higher cell capacity but can be recharged fewer times than NiCd. However calculations show that NiMH batteries may have higher total work capacity during the full lifetime of the battery.

According to information from industry and the literature, NiMH has higher cell capacity but can be recharged fewer times than NiCd over the battery life time. For this study, a number of major producers of professional cordless power tools were contacted and interviewed about the typical attainable number of recharging cycles for their NiCd and NiMH power tool batteries. Based on these data, along with other typical data for the battery types, two examples were calculated to illustrate the relation between battery capacity, recharging cycles and total capacity over the battery life time for professional cordless power tools. The examples are shown in the boxes below.

Example 1 illustrates that for realistic battery capacities and recharging cycles for a 12 Volt power tool (a typical size), the NiMH batteries may have higher total work capacity during the full life time of the battery.

Example 2 use the same set of numbers to illustrate that in order to obtain the same work as from a NiCd battery over its life time, the NiMH battery would only have to stand 670 recharging cycles; that is slightly

less than the typical cycles estimates provided by NiMH market leaders in Nordic countries Makita and Bosch.

It should be noted that other factors, such as partial recharges and self-discharge, may influence the actual usable life time capacity of both battery types. The examples indicate however, that the choice of battery type does not significantly influence the total consumption - and thereby the waste tonnage generated - of professional cordless power tools.

Example 1: Life time capacity with typical parameter values

Typical battery capacities, pro power tools, shop observations in DK 2004.				
NiCd	2	Ah		
NiMH	3	Ah		
Typical cycles, pro power tools, interviews 2004				
NiCd	1000	Cycles		
NiMH	750	Cycles		
Voltage in example				
NiCd	12	Volt		
NiMH	12	Volt		
Calculated battery effect per full cycle (Volt * Ah):				
NiCd	24	Wh/cycle		
NiMH	36	Wh/cycle		
Calculated total effect over battery life, if all capacity is used (Wh/cycle * cycles):				
NiCd	24000	Wh	100%	
NiMH	27000	Wh	113%	of NiCd capacity

Example 2: Break even cycle number for NiMH at equal life time capacity

Typical battery capacities, pro power tools, shop observations in DK 2004.		
NiCd	2	Ah
NiMH	3	Ah
Voltage in example		
NiCd	12	Volt
NiMH	12	Volt
Calculated battery effect per full cycle (Volt * Ah):		
NiCd	24	Wh/cycle
NiMH	36	Wh/cycle
Total effect over battery life, if all capacity is used (Wh/cycle * cycles):		
NiCd	24000	Wh
Total effect over battery life equal to 100% of NiCd capacity		
NiMH	24000	Wh (constant in this example)
Typical cycles, pro power tools, interviews 2004		
NiCd	1000	Cycles
Cycles at break even with NiCd life time capacity (with NiCd at 1000 cycles); (Wh in battery life divided by Wh/cycle):		
NiMH	670	Cycles

NiMH is accepted by professionals

Some of the major producers recommend - or sell almost exclusively - NiMH to professionals, but one major producer recommends NiCd to professionals. NiMH is accepted by high end users in cold climate. One of three major importers (retailer chains) of cordless power tools in Greenland supplies only NiMH power tools to professionals and had no complaints from users about their performance.

NiMH recommended by producers

A number of major producers present on the Nordic markets were asked which battery type they recommended to their customers.

Some of the major producers, Bosch, Makita, Hilti and Hitachi, recommend - or sell almost exclusively - NiMH to professionals. Bosch and Makita expressed the following reasons for their recommendations:

Larger battery capacities

No NiCd tax (in Denmark and Sweden)

No memory effect - batteries can be charged partially with no adverse effect on the battery

Dewalt (sold by Black & Decker) recommends NiCd to professionals, principally due to poorer low temperature performance of NiMH batteries.

Bosch recommends NiCd batteries to private consumers, because NiCd's regain full capacity with fewer recharges than NiMH's after some months of inactivity (capacity loss due to self-discharge; private consumers do often not use their power tools on a regular basis). Black & Decker's power tools to private consumers are almost solely equipped with NiCd batteries.

NiMH accepted by high end users in cold climate

The substantial sales of NiMH-driven professional cordless power tools indicate in it self that the professionals accept these machines. For this study a number of Swedish professional users of cordless power tools were interviewed in order to get some indications of their experiences with NiMH-driven power tools in a cold climate market dominated for a number of years by NiMH-driven power tools due to the high Swedish NiCd tax. Of the limited number of carpenters and other craftsmen who were interviewed and were aware which batteries their cordless power tools were equipped with, no users expressed having had problems with NiMH-driven tools. A few of them used NiMH power tools without problems outdoors on regular basis in Kiruna in the North of Sweden.

Also two of three major importers (retailer chains) of cordless power tools in Greenland were interviewed for this study. One of them supplied only NiMH power tools to professionals and had no complaints from users about their performance.

Private consumers focus less on performance

Large numbers of very low price No Name cordless power tools have been sold to private consumers through super markets and Do-It-Yourself centres during the last years. Average private consumers have limited demands to tool performance, and focus on price. In Denmark, these are almost exclusively equipped with NiMH batteries today.

Temperature performance of NiMH

The extensive sales of NiMH-driven power tools in the Nordic countries indicate that the lower temperature operation limits may perhaps not be a major impediment. Improvements are in development which enables NiMH batteries to operate better at high temperatures.

Both NiCd and NiMH batteries work best, and are most optimally recharged at moderate temperatures. According to the information ob-

tained, this temperature interval is somewhat smaller for NiMH than for NiCd, that is: NiMH does not operate quite as effectively at very low and very high temperatures as NiCd's. The extensive sales of NiMH-driven power tools in the Nordic countries to professional users craving optimal performance, the information on NiMH use in Greenland, and Swedish professional user's experiences indicate however, that the lower temperature operation limits may perhaps not be a major impediment for most European NiMH users. As regards high temperatures, industry sources inform that improvements are in development which enables NiMH batteries to operate better at high temperatures.

Resumé (summary in Danish)

Denne rapport beskriver forsyningssituationen for batteriværktøj i Norden og gør rede for de vigtigste tekniske faktorer der påvirker substitution af NiCd-batterier i denne sektor. NiMH-drevet batteriværktøj sælges i store mængder i dag, især til professionelle brugere. Adskillige store producenter af batteriværktøj anbefaler NiMH til professionelle. Rapporten præsenterer nye data som måske kan bidrage til processen med at skabe bæredygtig regulering af NiCd-batterier i EU.

Det giftige tungmetal cadmium anvendes i genopladelige nikkel-cadmium (NiCd) batterier og spredes i miljøet, bl.a. ved behandling af affald som indeholder batterier der ikke er blevet frasorteret. Batteriværktøj udgør i øjeblikket det største enkelt-bidrag af transportable nikkel-cadmium (NiCd) batterier til det danske samfund - og sandsynligvis i mange andre europæiske lande. De fleste andre anvendelser af transportable NiCd-batterier er blevet substitueret i dag på grund af alternative genopladelige batteriers bedre ydelse og muligvis på grund af tidligere planer om forbud mod NiCd-batterier i ældre udkast til et nyt EU-batteridirektiv. Derimod er NiCd-batterier forblevet den vigtigste energikilde for batteriværktøj indtil for nylig. Denne rapport dokumenterer at alternativerne - hovedsagelig af nikkel-metal-hydrid (NiMH) typen - i nogle af de nordiske lande er tæt på at overhale NiCd på markederne for batteriværktøj. Dette er et resultat af pres fra myndighederne (NiCd-afgift i Sverige og Danmark) og en forbedret ydelse af NiMH-batterier for el-værktøj. Også i Norge og Finland, som ikke har nogen specifik afgift på NiCd-batterier, sælges NiMH-drevet batteriværktøj i store mængder i dag, især på det professionelle marked hvor der stilles store krav til kvalitet og pålidelighed. Adskillige store producenter af batteriværktøj anbefaler nu NiMH til professionelle brugere. Rapporten beskriver forsyningssituationen for batteriværktøj i Norden og gør rede for de vigtigste tekniske faktorer, der påvirker substitutionen af NiCd-batterier i denne sektor. Rapporten præsenterer nye data, som måske kan bidrage til processen med at skabe bæredygtig regulering af NiCd-batterier i EU.

NiMH's markedsandel i Norden

NiMH har nu opnået betydelige markedsandele - både blandt professionelle og private forbrugere - i de nordiske lande. I 2003 blev andelen af NiMH i Danmark for professionelle værktøjer skønnet til ca. 60 %, og den var højst sandsynligt fortsat stigende i 2004.

Som et resultat af teknologiske fremskridt og miljømæssige fordele blev batteriværktøj med NiMH introduceret på det europæiske marked omkring 1997 som alternativ til NiCd. Genopladelige NiMH og Li-ion batterier havde allerede på det tidspunkt substitueret en stor del af NiCd-anvendelsen i forbrugerelektronik, fx i mobiltelefoner og bærbare pc'er. Den højere batterikapacitet pr. genopladning var en attraktiv egenskab for de professionelle forbrugere af batteriværktøj, og i de første par år var NiMH kun at finde i avanceret batteriværktøj til professionelle. Men ved århundredeskiftet kom NiMH også inden for økonomisk rækkevidde for private forbrugere i Danmark, og formodentligt også i andre nordiske lande, i form af lavpris gør-det-selv batteriværktøj. NiCd-afgiften i Danmark, og formodentligt også i Sverige, muliggjorde brugen af de dyrere NiMH-batterier. Det er vanskeligt at opgøre salget af dette såkaldt "No Name" batteriværktøj præcist, men de tilgængelige data tyder på at No Name NiMH-batteriværktøj muligvis udgør op til omkring halvdelen af salget af gør-det-selv batteriværktøj i Danmark i dag. Traditionelle, velkendte mærker af batteriværktøj tilbyder stadig hovedsageligt NiCd-drevne værktøjer til gør-det-selv segmentet. En undtagelse er dog introduktionen af en Li-ion-drevet skruemaskine i 2003.

NiMH's andel på de nordiske markeder

Data fra denne undersøgelse - og en nyligt udført opgørelse for Danmark - viser at NiMH nu har opnået betydelige markedsandele - både blandt professionelle og private forbrugere i Norden. Tabel 2-2 giver en oversigt over NiMH-drevet batteriværktøjs anslåede markedsandele i de nordiske lande.

Det er vigtigt at lægge mærke til en forskel mellem de nordiske lande: Sverige og Danmark har specifikke afgifter på NiCd-batterier, herunder batterier til batteriværktøj. Dette er ikke tilfældet for Island, Finland og Norge. De svenske og danske markeder har derfor været under ekstra pres for at skifte over til NiMH. Det er imidlertid interessant i dette perspektiv at observere at NiMH også har betydelige markedsandele i Norge og Finland.

Table 3 Markedsandele for NiMH-drevet batteriværktøj i 2003/2004 i Norden

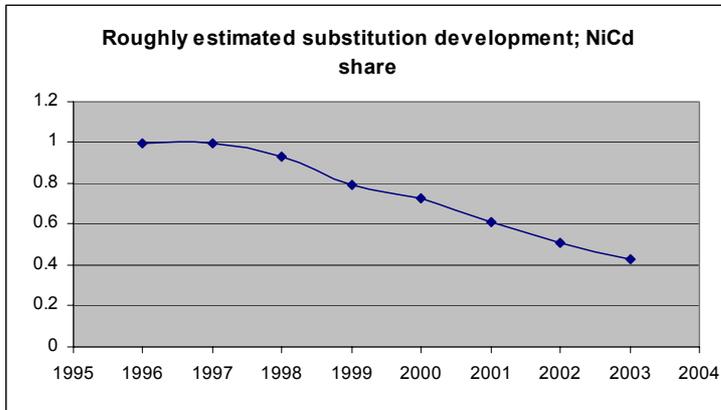
Land og produkt underkategori	NiMH-andel af marked (% af antal batteri værktøjer solgt)*1	Bemærkninger
<i>Danmark</i>		
Professionelt batteriværktøj	60 %	2003, baseret på en undersøgelse fra 2004 foretaget i Danmark (Maag and Hansen, 2004); sandsynligvis større i 2004
Gør-det-selv	30-50 %	Groft skøn fra denne undersøgelse
<i>Island</i>		
Totale marked		Sandsynligvis kun en mindre andel af NiMH i 2004, baseret på data fra denne undersøgelse
<i>Finland</i>		
Totale marked	30 %	Skønnet af TKL, Finland, 2004
<i>Norge</i>		
Professionelt batteriværktøj	50-60 %	Skønnet ud fra detaljerede data i denne undersøgelse, 2004
Gør-det-selv		Ukendt, men kan måske være betydelig (måske i nærheden af niveauerne i Danmark eller Sverige)
<i>Sverige</i>		
Professionelt batteriværktøj	90 %	Skønnet af LEH, Sverige, 2004
Gør-det-selv	35 %	Skønnet af LEH, Sverige, 2004

Note: *1 NiCd og NiMH dominerer i øjeblikket markedet, men en tredje batteritype, Li-ion, forventes at have en lille, men stigende markedsandel i Norden.

Udviklingen af NiMH's markedsandele

For det professionelle marked i Danmark blev der foretaget en vurdering af NiCd-batteriers andel af det totale salg af batteriværktøj i en nylig undersøgelse udført for Miljøstyrelsen. Vurderingen var baseret på detaljerede oplysninger fra individuelle producenter. Andelen af NiMH for professionelle værktøjer i 2003 blev skønnet til ca. 60 %, og på basis af oplysninger fra producenter var den højst sandsynlig stadig stigende i 2004. Da adskillige af de vigtigste el-værktøjsmærker er de samme i alle de nordiske lande, har tendensen muligvis været den samme i de andre nordiske lande. Figur 2-2 viser det gradvise fald i NiCd's andel af markedet for professionelt batteriværktøj i Danmark. Figuren er baseret på detaljerede oplysninger fra dominerende producenter repræsenteret på det danske marked.

Figur 2 NiCd-andel af det totale batterisalg med professionelt batteriværktøj (fra Maag and Hansen, 2004)



Elværktøjer med Li-ion batterier

En ny udvikling er introduktionen af batteriværktøj med Li-ion batterier på markedet i 2003. Hermed følges tendensen fra andre elektriske og elektroniske produkter i bestræbelserne efter et stadigt stigende effekt/vægt forhold til bærbart udstyr.

NiMH's kapacitet set over levetiden

NiMH celler har højere kapacitet, men kan genoplades færre gange end NiCd. Beregninger viser imidlertid at NiMH-batterier kan have større total arbejds kapacitet i løbet af batteriets fulde levetid.

Ifølge informationer fra industrien og litteraturen har NiMH større cellekapacitet, men kan genoplades færre gange end NiCd i løbet af batteriets levetid. I denne undersøgelse blev et antal større producenter af professionelt batteriværktøj kontaktet og interviewet om det typiske opnåelige antal opladninger med deres NiCd- og NiMH batterier. Baseret på disse data, sammen med andre typiske data for batterityperne, blev der beregnet to eksempler til illustration af sammenhængen mellem batterikapacitet, antal opladninger og den totale kapacitet gennem batteriernes levetid for professionelt batteriværktøj. Eksemplerne er vist i boksene nedenfor.

Eksempel 1 illustrerer at for realistiske batterikapaciteter og opladningsantal for et 12Volts batteriværktøj (typisk størrelse) kan NiMH-batterierne have større total arbejds kapacitet end NiCd set over batteriets fulde levetid.

Eksempel 2 bruger det samme sæt tal til at illustrere at for at opnå det samme arbejde som et NiCd-batteri gennem dets levetid, skulle NiMH-batteriet kun klare 670 opladninger; dvs. en smule mindre end de typiske opladnings-tal, der er oplyst af førende producenter på NiMH-markedet i Norden - Makita og Bosch.

Det bør bemærkes at andre faktorer, så som delvise genopladninger og selvafladning, kan have indflydelse på begge batteritypers faktisk anvendelige levetidskapacitet. Eksemplerne indikerer imidlertid at valget af batteritype ikke har nogen betydelig indflydelse på det totale forbrug - og således den genererede affaldsmængde - af professionelt batteriværktøj.

Eksempel 3: Levetidskapacitet med typiske parameterværdier

<i>Typiske batterikapaciteter, professionelt batteriværktøj, butiksobservationer i DK 2004</i>				
NiCd	2	Ah		
NiMH	3	Ah		
<i>Typisk antal opladninger i levetid, professionelt batteriværktøj, interviews 2004</i>				
NiCd	1000	Opladninger		
NiMH	750	Opladninger		
<i>Spænding i eksempel</i>				
NiCd	12	Volt		
NiMH	12	Volt		
<i>Beregnet batterieffekt pr. fuld opladning (Volt * Ah):</i>				
NiCd	24	Wh/opladning		
NiMH	36	Wh/opladning		
<i>Beregnet totaleffekt over batteri-levetiden, hvis al kapacitet bruges (Wh/opladning * antal opladninger):</i>				
NiCd	24000	Wh	100%	
NiMH	27000	Wh	113%	af NiCd-kapacitet

Eksempel 4: Break even-cyklusantal for NiMH ved ens levetidskapacitet

<i>Typiske batterikapaciteter, professionelt batteriværktøj, butiksobservationer i DK 2004</i>		
NiCd	2	Ah
NiMH	3	Ah
<i>Spænding i eksempel</i>		
NiCd	12	Volt
NiMH	12	Volt
<i>Beregnet batterieffekt pr. fuld opladning (Volt * Ah):</i>		
NiCd	24	Wh/cyklus
NiMH	36	Wh/cyklus
<i>Total effekt gennem batterilevetid, hvis al kapacitet bruges (Wh/opladning * antal opladninger):</i>		
NiCd	24000	Wh
<i>Total effekt gennem batterilevetid, lig med 100% af NiCd-kapacitet</i>		
NiMH	24000	Wh (konstant i dette eksempel)
<i>Typisk antal opladninger, professionelt batteriværktøj, interviews 2004</i>		
NiCd	1000	Cykler
<i>Beregnet antal opladninger der giver samme levetidskapacitet som NiCd (med NiCd ved 1000 opladninger); (Wh i batterilevetid divideret med Wh/opladning):</i>		
NiMH	670	Opladninger

NiMH accepteres af professionelle

Nogle af de største producenter anbefaler - eller sælger næsten udelukkende - NiMH til professionelle, men en enkelt stor producent anbefaler NiCd til professionelle. NiMH accepteres af krævende brugere i koldt klima. En ud af tre større importører af batteriværktøj i Grønland sælger kun NiMH-batteriværktøj til professionelle og har ikke fået nogen reklamationer over værktøjernes ydeevne fra brugerne.

NiMH anbefales af producenter

En række store producenter repræsenteret på de nordiske markeder er blevet spurgt hvilke batterityper de anbefaler deres kunder.

Nogle af de største producenter, Bosch, Makita, Hilti og Hitachi anbefaler eller sælger næsten udelukkende - NiMH til professionelle. Bosch og Makita gav udtryk for de følgende grunde til deres anbefaling:

- Større batterikapacitet
- Ingen NiCd-afgift (i Danmark og Sverige)
- Ingen memory-effekt - batterier kan oplades delvist uden negativ påvirkning af batteriet.

Dewalt (sælges af Black & Decker) anbefaler NiCd til professionelle, hovedsageligt på grund af NiMH-batteriers ringere ydeevne ved lave temperaturer.

Bosch anbefaler NiCd-batterier til private forbrugere, fordi NiCd batterier genvinder fuld kapacitet med færre genopladninger end NiMH efter nogle måneders inaktivitet (kapacitetstab på grund af selvafladning; mange private forbrugere anvender ikke deres batteriværktøj regelmæssigt). Black & Deckers batteriværktøj til private forbrugere er næsten udelukkende forsynet med NiCd-batterier.

NiMH accepteres af krævende brugere i koldt klima

Det betydelige salg af NiMH-drevet professionelt batteriværktøj indikerer i sig selv at de professionelle brugere accepterer disse maskiner. Til brug for denne undersøgelse blev svenske professionelle brugere af batteriværktøj interviewet med det formål at få nogle indikationer af deres erfaringer med NiMH-drevet batteriværktøj i et koldt klima, på et marked som gennem nogle år har været domineret af NiMH-drevet batteriværktøj på grund af den høje svenske NiCd-afgift. Af det begrænsede antal tømrere og andre håndværkere, som blev interviewet og var bevidst om hvilke batterier deres batteriværktøj var udstyret med, var der ingen brugere der gav udtryk for at have haft problemer med NiMH-drevne værktøjer.

Nogle få af dem brugte NiMH-batteriværktøj uden problemer udendørs regelmæssigt i Kiruna i Nordsverige.

Også to ud af tre store importører (detailkæder) af batteriværktøj i Grønland blev interviewet til denne undersøgelse. En af dem leverede kun NiMH-batteriværktøj til professionelle og havde ikke modtaget nogen reklamationer fra brugerne over værktøjernes anvendelighed.

Private forbrugere fokuserer mindre på ydeevne

Et stort antal meget billige No Name batteriværktøjer er blevet solgt til private forbrugere gennem supermarkeder og byggemarkeder i de senere år. Den gennemsnitlige private forbruger stiller begrænsede krav til værktøjets ydeevne og fokuserer på prisen. I Danmark er disse værktøjer næsten udelukkende forsynet med NiMH-batterier i dag.

NiMH's temperaturfølsomhed

Det store salg af NiMH-drevet batteriværktøj i Norden indikerer at driftsbegrænsningerne på grund af lavere temperatur måske ikke er nogen stor hindring. Forbedringer er under udvikling, som vil muliggøre en bedre funktion af NiMH-batterier ved høje temperaturer.

Både NiCd- og NiMH-batterier fungerer bedst - og oplades mest optimalt - ved moderate temperaturer. Ifølge de indhentede oplysninger er dette temperaturinterval noget mindre for NiMH end for NiCd, dvs.: NiMH fungerer ikke helt så effektivt ved meget lave og meget høje temperaturer som NiCd. Det store salg af NiMH-drevet batteriværktøj i Norden til professionelle brugere, der ønsker optimal ydelse og kvalitet, sammenholdt med oplysningerne om NiMH anvendelse i Grønland og svenske professionelle brugeres erfaringer, tyder på at begrænsninger i driften ved lavere temperaturer muligvis ikke er nogen stor hindring for de fleste europæiske NiMH brugere. Hvad angår høje temperaturer, oplyser industrikilder at forbedringer er på vej, som vil få NiMH-batterier til at fungere bedre ved høje temperaturer.

1 Introduction to cordless power tools

Product description

The sales of battery powered hand tools, also called cordless power tools, are dominated by screwing/drilling machines. Contrary to many other uses of rechargeable batteries, the alternatives to NiCd batteries have not been generally acknowledged as technically advantageous until recently, where the higher energy capacities of NiMH is acknowledged as an advantage by many high end professional users in the Nordic countries.

Three different sub-categories of cordless power tools with different quality are on the market and must be distinguished carefully: Professional machines, high end Do-It-Yourself machines and very low price “No Name” machines.

The sales of battery powered hand tools are dominated by screwing/drilling machines. Examples of other tools with minimal contributions to the total sales in this product category are hammer drills, circular saws, sanding machines, and certain electrical gardening hand tools.

Today the large majority of batteries used for cordless power tools are readily replaceable battery packs produced specifically for the individual product or product series. These battery packs are not built into the tool itself, and are taken out of the tool when being recharged. The sales are dominated by machines with voltages at or above 12V, meaning that these battery packs consist of 10 or more connected battery cells in a common plastic casing (individual cell voltage is 1.2 V for NiCd and NiMH). If any, only a small number of low voltage specialty tools are equipped with build-in batteries.

The product category has been dominated by NiCd-batteries, but NiMH-batteries were introduced on market in 1997/1998 and have, after a slow start, been gaining higher parts of the market during the last few years. As the newest development, Li-ion batteries have been introduced with one product - a small screwing machine - by one producer in 2003.

Contrary to many other uses of rechargeable batteries, the alternatives to NiCd batteries have not been generally acknowledged as technically advantageous until recently, where the higher energy capacities of NiMH is acknowledged as an advantage with NiMH batteries by many high end professional users in the Nordic countries.

Sub-groups of products to different user segments

The cordless power tools market is split in two distinct product groups designed for two segments; professional users such as carpenters and other craftsmen, and the so-called Do-It-Yourself segment, meaning mainly private users. This distinction is important; the actual products are not the same, they differ in price and quality. Some high brand producers offer both professional and do-it-your self power tools, while others only offer power tools in one of the categories.

It is equally important to note that, within the Do-It-Yourself product group, a distinct sub-category is very low price cordless power tools, often designated "No Name" tools; which are not offered by high brand power tool producers.

Sub-groups' battery types and product characteristics

The products aimed at professional use are built for higher strains and more continuous use (higher battery capacity, better bearings, gears etc.). They are generally heavier with higher battery voltage (meaning more battery cells per tool) and higher cell capacity. Since the introduction of cordless power tools, the professional machines have been equipped with NiCd batteries, but during the last 4-6 years NiMH has gained substantial parts of the market. Most producers of professional machines offer both NiMH and NiCd-driven power tools, but some market leaders are rapidly moving away from NiCd's while others still recommend NiCd batteries (see section 9.1). The Nordic professional market has been dominated by well known international brands ever since cordless power tools gained a significant market.

The high brand Do-It-Yourself power tools are almost exclusively equipped with NiCd batteries today.

The No Name tools are typically sold at prices below half of the price of (apparently) comparable high brand Do-It-Yourself cordless power tools. Their performance may in some case be clearly inferior to high brand tools; less strength at same voltage, apparently less capacity, very quick self discharge. Some importers of No Name power tools state that their cordless power tools have standards comparable to high quality brands.

Because No Name cordless power tools are partly imported and sold by other channels than the traditional tools importers, their share of the national markets is more difficult to estimate at all the Nordic markets. At their introduction on the market in the late 1990's, the No Name products were equipped with NiCd-batteries, but since 2001/2002, No Name cordless power tools with NiMH-batteries have been dominating the Danish Do-It-Yourself market.

2 Denmark

2.1 Consumption pattern

The share of NiMH for professional tools was estimated to about 60% in 2003, and it is most likely still on the rise in 2004. 30-50% of the Do-It-Yourself sales are equipped with NiMH batteries in 2004.

The consumption of NiCd batteries for power tools in Denmark has been quantified and described in detail in an ongoing study initiated by the Danish EPA (Maag and Hansen, 2004). For a qualitative description of the situation see the general introduction in section 3. Maag and Hansen (2004) estimated the total sales of NiCd batteries in power tools based on a detailed study of relevant input data. Danish sales are presented in table 4-1.

Table 2.1.1 Estimated NiCd-battery sales with cordless power tools (Maag and Hansen, 2004).

Year	NiCd batteries for PRO power tools	NiCd batteries for DIY power tools	Total, NiCd battery units for power tools
<i>Pcs/y</i>			
1996	117,263	111,030	228,300
1997	140,747	152,618	293,400
1998	157,320	143,853	301,200
1999	154,148	183,048	337,200
2000	171,538	176,578	348,100
2001	147,382	167,890	315,300
2002	110,065	150,962	261,000
<i>Tonnes/y</i>			
1996	71	54	125
1997	89	79	168
1998	102	77	179
1999	105	101	206
2000	124	95	219
2001	110	89	199
2002	82	84	166

The sales estimates shown in table 4-1 for NiCd batteries were based on, among other data, the sales statistics of the Danish association of suppliers of transportable power tools and gardening machines (LTEH) for all types of (high brand) power tools, including NiMH-driven power tools (Li-ion was not introduced at that time on the Danish market).

A summary of the sales statistics of the Danish association of suppliers of transportable power tools and gardening machines for cordless power tools is presented in table 4-2. These statistics include about 85-95% of the total sales of high brand power tools in Denmark, but do not include sales of low-price No Name power tools.

The sales of low-price No Name power tools have been rising during the last 5-6 years in Denmark, and annual sales may in 2004 approach the proportions of high brand Do-It-Yourself power tools shown in table 4-2. Based on very preliminary data, the sales of No Name cordless power tools are roughly estimated at 30-50% of the total Do-It-Yourself market (this means that another 30-50% should be added to the numbers shown for Do-It-Yourself cordless power tools in table 4-2).

Table 2.1.2 Sales of high brand cordless power tools registered by LTEH, in 1000 pcs/y (Maag and Hansen, 2004).

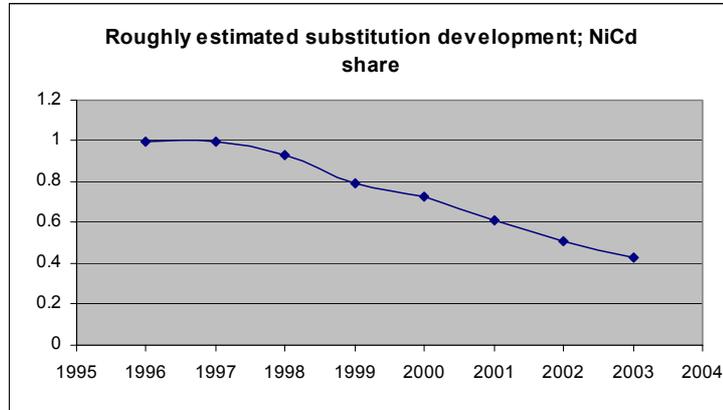
Cordless power tools' sales registered by LTEH	1996	1997	1998	1999	2000	2001	2002
Professional power tools, 1000 pcs/y	51	62	74	86	106	108	95
Do-It-Yourself power tools, 1000 pcs/y	59	82	77	98	95	98	88
Totals, 1000 pcs/y	111	143	151	184	200	207	183

2.2 NiMH and Li-ion market shares

Professional cordless power tools

For the professional market, Maag and Hansen (2004) formed a market estimate for the share of NiCd batteries of the total sales of cordless power tools in Denmark. The estimate was based on detailed information from individual producers. The share of NiCd for professional tools was estimated as shown in Figure 4-1. In 2003 about 60% was NiMH, and based on detailed information from dominating producers it is most likely still on the rise in 2004.

Figure 2.2.1 NiCd share of total battery sales for professional power tools (from Maag and Hansen, 2004)



Do-It-Yourself cordless power tools

For Do-It-Yourself cordless power tools, NiCd has so far dominated the high brand sales, in spite of a battery tax of 6 DKK (roughly 0.8 Euro) per NiCd cell, meaning about 8 Euro for a 12 Volt power tool with one battery unit in the sales package.

In the beginning, the No Name products were marked as equipped with NiCd-batteries, but since 2001/2002 the No Name market for cordless power tools have been dominated by NiMH-batteries.

Based on very preliminary information on the sales of No Name cordless power tools, and good data on high brand Do-It-Yourself tools, a rough preliminary estimate is that 30-50% of the Do-It-Yourself sales are equipped with NiMH batteries in Denmark, in 2004.

2.3 Greenland - cordless power tools supply and performance

For this study two out of the three major supply chains of tools and building materials in Greenland were contacted with questions on the supply situation, their recommendations to users and any general experiences with cordless power tools in the extreme temperature conditions of Greenland. From both chains, the information given here covers all their shops in Greenland.

One chain sell only one brand of professional power tools, Bosch with NiMH batteries, and one brand of do-it-your power tools, Skil (also owned by Bosch), with NiCd batteries. Craftsmen prefer the strong machines. The chain has not had any negative response to the NiMH power tools.

The other chain sells only to professionals. They recommend NiCd tools for better performance and mention Makita and Dewalt as major brands for professionals in Greenland. As mentioned in section 9.1, these two brands produce power tools with both NiMH and NiCd, but for Makita, NiMH is generally dominating on the Nordic markets and for Dewalt, NiCd is generally dominating.

3. Finland

3.1 Consumption pattern

In 2003 30% of sales of cordless power tools were with NiMH, while the remaining 70% were with NiCd batteries. Some professionals prefer NiMH-batteries because of their higher capacity; also some environment protection-orientated hobby users prefer these tools. Some professionals working outdoor prefer NiCd batteries because the Ni-MH-batteries do not have enough performance at low temperatures.

In Finland, unlike Denmark and Sweden, no special taxes are charged for NiCd batteries, which means that the market has evolved according to market forces.

Consumption data for cordless power tools in Finland have been obtained from the Association of Finnish Technical Traders (TKL). TKL have provided data for the total Finnish market including estimates for sales of companies which are not members of the TKL.

For 2003, the provided data include estimates of the distribution of sales on battery voltages and consumer segments, and corresponding battery tonnages. These data are summarised in table 5-1.

NiMH and Li-ion shares of the market

TKL has provided their estimate of the distribution of national cordless power tools sales on NiCd versus NiMH batteries. On an overall basis TKL estimate that 30% of current sales of cordless power tools were equipped with NiMH batteries 2003, while the remaining 70% are equipped with NiCd batteries. As regards Li-ion batteries, their use is very limited in Finland presently according to the TKL.

A similar pattern was observed at one shop visit and one telephone interview in/with a chain of retail shops for tools and building materials in the Helsinki area of Finland. For all the well known brands represented in these shops, professional power tools with both NiMH and NiCd were offered. The offered high brand Do-It-Yourself power tools were all equipped with NiCd batteries.

Calculated battery sales

Calculated total battery sales with cordless power tools are presented in table 5-2. Estimates are based on TKL's assumption that each power tool is sold with 2 battery units in each sales package, combined with the authors observations in Denmark and Finland that professional power tools

always have 2 batteries in the sales package, while Do-It-Yourself power tools are only equipped with 2 batteries in special sales campaigns. In the calculations, the minimum estimate is based on 1.5 battery units per sales package on average, while the maximum is based on 2 battery units per sales package.

Table 3.1.1 Total sales of cordless power tools in Finland in 2003, distributed on professional and Do-It-Yourself power tools (TKL, 2004). Battery sales in kg/year are as calculated by TKL

Voltage	Total	Weight of battery	of which	Total weight of cells	Profes-sional	Do-It-Yourself
	pcs	kgs	cell 84%	kgs*1	%	%
below 7.2V	14167		0.15	4250	78	22
7.2V	3542	0.38	0.32	2267	78	22
9.6V	9934	0.48	0.4	7947	14	86
12V	91563	0.68	0.57	104382	53	47
14.4V	59874	0.86	0.72	86219	43	57
18V	19958	1.04	0.87	34727	43	57
24V	19958	1.4	1.18	47101	43	57
Total	218996			286892		

Notes: Note that TKL made the calculations based on that one power tool has two batteries in sales package, that means differently than in table 5-2.

Table 3.1.2 Battery sales for cordless power tools in Finland 2000-2003, pcs/year

Voltage	2003		2002				2001		2000			
	Batteries /year *1		NiCd		NiMH		Batteries /year		Batteries /year			
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
below												
7.2V	21300	28300	14900	19800	6400	8500	10700	14200	14200	19000	15300	20400
7.2V	5300	7100	3700	5000	1600	2100	2700	3600	3600	4700	3600	4800
9.6V	14900	19900	10400	13900	4500	6000	18000	24100	10900	14600	17900	23900
12V	137300	183100	96100	128200	41200	54900	123200	164200	113900	151800	109500	145900
14.4V	89800	119700	62900	83800	26900	35900	71700	95600	62500	83400	65600	87400
18V	29900	39900	21000	27900	9000	12000	23900	31900	20800	27800	21900	29100
24V	29900	39900	21000	27900	9000	12000	26900	35900	26800	35800	27900	37100
Total	328400	437900	230000	306500	98600	131400	277100	369500	252700	337100	261700	348600

Notes: Estimates are based on TKL's assumption that each power tool is sold with 2 battery units in each sales package, combined with the authors observations in Denmark and Finland that professional power tools always have 2 batteries in the sales package, while Do-It-Yourself power tools are only equipped with 2 batteries in special sales campaigns. In the calculations, the minimum estimate is based on 1.5 battery units per sales package on average, while the maximum is based on 2 battery units per sales package.

3.2 Experience with NiMH and NiCd performance - selected aspects

From Finland, only the TKL and two major tool shops/Do-It-Yourself centres have been asked questions relating to NiMH and NiCd performance.

As regards NiMH, TKL states that certain professionals prefer these batteries because of their higher capacity; also some environment protection-orientated hobby users prefer these tools. As regards NiCd, TKL states that professionals who work outdoor e.g. in construction business, prefer power tools with NiCd batteries because the Ni-MH-batteries do not have enough performance at low temperatures. TKL does not know of any geographical differences in Finland as regards these aspects.

TKL states that cordless power are usually not protected in any way during the winter time. TKL states that according to manufacturers' instructions it is desirable to warm the Ni-MH-battery up before using it at low temperatures; Ni-Cad –batteries do not have to be warmed before use.

4. Iceland

One of three suppliers recommends and sells NiMH-driven power tools and has only good experiences with them. The other two suppliers have so far only sold NiCd-driven power tools

In Iceland, there is no trade association that maintains statistics on cordless power tools sales. The national bureau of statistics have statistics on power tools, but the data are not distributed on cordless and other electrical hand tools, and are therefore of limited relevance here.

With the assistance of the Icelandic Environment and Food Agency (UST), four supplier chains dominating the power tools market have been contacted for this study, and three of these have accepted to supply information.

Among the three importers, a total of between 5000 - 8000 cordless power tools are sold per year in recent years (2002-2004). Their total market share is not clear, but a rough estimate of the total market in Iceland would be 10,000 - 15,000 cordless power tools per year. Of these, at least the half likely have two batteries per sales package (the professional machines and some of the Do-It-Yourself machines).

About half of the sales are supplied to professionals. Brands available in Iceland include Dewalt, Black & Decker, Makita, Hitachi, and low price No Name power tools (and possibly others).

One of the three companies recommends and sells NiMH-driven power tools and has only good experiences with them. The other two companies have so far only sold NiCd-driven power tools (one plan to introduce NiMH in the near future).

5. Norway

The total share of NiMH-driven cordless professional power tools can be estimated at 50-60%. Data for the Do-It-Yourself market are not available. Some users prefer NiMH-driven power tools because NiMH batteries can work longer per charge. Others prefer NiCd because the batteries have a longer lifetime

In Norway, unlike Denmark and Sweden, no special taxes are charged for NiCd batteries in power tools¹, which means that the market has evolved according to market forces.

5.1 Consumption pattern

Estimates of total sales of cordless power tools in Norway in the last years are presented in table 5.1.1 The estimates are based on data from an informal network of importers of hand tools to Norway; estimated imports from importers outside the network are included.

NiMH market share

No statistics are available on the current market share of NiMH-driven power tools in Norway. Individual importers covering about 80% of the Norwegian market for professional power tools were contacted for this study and interviewed about the share of NiMH batteries in their current (2003-2004) sales. On this basis, the total share of NiMH-driven cordless professional power tools can be estimated at 50-60%, depending on whether the 80% covered also represent the trend for the remaining 20% of minor brands on the market. The importers were well informed about the share of NiMH of their own sales, but their views on the general situation on the Norwegian market varied significantly, depending on their individual sales situation.

As for the Do-It-Yourself market, data for a qualified estimation of the NiMH share are not available. High brand Do-It-Yourself power tools are equipped with NiCd except for a - probably - limited but rising sale of Li-ion powered screwing machines. According to industry sources, the No Name power tools may constitute around 30-60% of the Norwegian Do-It-Yourself market. As some similarities with the Danish market may be likely, a part of these are expected to be NiMH-powered.

¹ Taxes are charged to finance collection activities for some other types of NiCd batteries.

Table 5.1.1 Estimated total sales of cordless power tools in Norway (based on data from importers), pieces/year *1.

	Total sales, pcs/y	Total sales, pcs/y	Total sales, pcs/y	Total sales, pcs/y
Voltage *	2003	2002	2001	2000
Professional cordless power tools				
2,4 V + 3,6 V	2000	2200	2200	2300
7,2 V + 9,6 V	2700	7600	10500	11000
12 V	39200	32700	37600	34100
13,2 V and larger	19900	16400	16900	15200
Hammer drills	1700	1900	1900	1900
Other cordless	10600	8000	16000	12700
Subtotal, Pro.	76100	68800	85100	77200
Do-It-Yourself cordless power tools				
2,4 + 3,6 + 4,8 V	10700	12100	68600	17000
Above 4,8 up to 7,2 V	4800	2100	0	-1600
from 9,6 V	2400	5500	23300	6600
from 12 V	40500	34400	55600	70700
13,2 V and larger	38500	19300	14800	16800
Other cordless	2400	3300	1400	2400
Subtotals, D-I-Y	99300	76700	163700	111900
Totals	175400	145500	248800	189100

Notes: Estimated from importers' sales statistics and their assumed coverage of the national market; rounded.

*: Entries with voltage only are drilling/screwing machines.

5.2 Experience with NiMH and NiCd performance - selected aspects

The contact point of the Norwegian importers network also supplied information on a number of other aspects. He underlined that he could not answer on behalf of the whole importers network.

To the question whether some users prefer NiMH-driven power tools, the answer was that NiMH batteries can work longer per charge (capacity is on at least 3,0 Ah today). To the same question for NiCd, the answer was: Yes, some prefer NiCd because the batteries have a longer lifetime. Can take higher number of charges.

As regards difference in extreme temperature performance, the respondent stated: NiCd can be used in a lower temperature than NiMH. Difference is about 10C. The difference is also for high temp. NiCd can take 90C and NiMH can withstand only 60 degrees C.

In Norway, according to the network contact point, cordless power tools are stored in the wintertime under "normal indoor" conditions, when not in use. The answer was "no" to the question: Must NiMH batteries (in power tools) be treated differently than NiCd batteries in winter conditions than NiCd batteries to perform adequately (storing, charging, discharging, other aspects)?

As regards memory effect and self-discharge, the question is not, according to the contact point, a difference between of the two types (NiMH and NiCd), but be between high and low battery quality: Extreme low-price cordless power tool batteries have memory and capacity problems. New high-price NiCd batteries do not have memory problems, and have up to 2,6 Ah capacity.

6. Sweden

6.1 Consumption pattern

Today 90% of the professional cordless power tools are sold with NiMH, the remaining 10% being NiCd-equipped. NiCd-equipped power tools seems to have the majority of the Do-It-Yourself market, in spite of the high taxes on NiCd batteries. About 65% of the sales of Do-It-Yourself power tools are NiCd-driven, while the remaining 35% are NiMH-driven.

Detailed data on sales of cordless power tools have been requested from relevant trade sources, but the data could not be made available for the project.

National official statistics have been retrieved and are presented in appendix 1. Such data may not necessarily give a precise picture of the consumption situation, but do probably give a hint of the magnitude.

NiMH and Li-ion market shares

According to information from the Swedish association of suppliers of electrical hand tools, LEH, 90% of the sales of professional cordless power tools are sold with NiMH today, the remaining 10% being NiCd-equipped. Also in Sweden, NiCd-equipped power tools seems to have the majority of the Do-It-Yourself market, in spite of the high taxes on NiCd batteries (300 SEK or about 33 Euros per kg NiCd battery). According to LEH, about 65% of the sales of Do-It-Yourself power tools are NiCd-driven, while the remaining 35% are NiMH-driven. With a typical battery weight of more than 0.6 kg, the NiCd tax would amount to around 20 Euros per battery for a 12 Volt powertool, or about 2½ times the Danish NiCd tax (60 DKK or about 8 Euros per 12 Volt battery).

According to the opinion of LEH, "NiCd's generally have better technology and efficiency, manages more recharging cycles and work better at cold temperatures than NiMH".

6.2 Swedish craftsmen's experience with NiMH

In order to get an impression of Swedish craftsmen's experiences with professional NiMH-driven power tools under Swedish conditions, a limited number of craftsmen were contacted and interviewed on the phone. Sweden was chosen for this purpose because of the high share of NiMH in the sales of professional cordless power tools combined with a cold winter climate.

It should be noted that no attempt has been made to interview so many users that statistical significant results could be achieved. The results presented below should be considered indicative.

A total of 20 craftsmen, mainly carpenters were reached by phone and were willing to be interviewed.

Five carpenters/craftsmen worked regularly or occasionally outdoors with cordless power tools and knew which kind of batteries their power tools were equipped with. All five had worked a number of years with cordless power tools and worked solely or mainly with NiMH (some had older machines with NiCd batteries along with the newer NiMH machines). None of them had experienced any problems with NiMH-driven power tools. Two of the interviewed craftsmen worked outside on a daily basis in Kiruna in the North of Sweden and had not experienced any problems with NiMH batteries. One of them noted that he kept his power tools indoor when not in use. All four bought their power tools based on other preferences than battery type; they followed the brand or chose strong machines with a "good grip in the hand".

Other four carpenters worked indoor and knew what kinds of batteries their power tools were equipped with. All had good experiences with NiMH-driven power tools, and could observe no difference between NiMH and NiCd batteries.

Another eleven carpenters interviewed worked with cordless power tools, but did not know which battery types their machines were equipped with.

7 Battery characteristics - selected aspects

NiMH has higher cell capacity but can be recharged fewer times than NiCd. However calculations show that NiMH batteries may have higher total work capacity during the full lifetime of the battery.

Some of the major producers recommend - or sell almost exclusively - NiMH to professionals, but one major producer recommends NiCd to professionals. NiMH is accepted by high end users in cold climate.

As examples, some aspects of battery performance and other developments are discussed here, for selected cordless power tool brands which are among the dominating brands in the Nordic countries and are also major brands on the European market. Data sources are mentioned in the text; most data are based on interviews with the producers.

7.1 Producers' recommendations of NiMH vs NiCd

There are distinct differences among the producer in the recommendations of NiMH versus NiCd.

Makita was the first brand to introduce NiMH batteries for power tools in 1997, and was a market leader on NiMH until recently. Bosch and Dewalt introduced NiMH slightly later (1998 in Denmark). In Denmark in 2004, Makita and Dewalt sell professional power tools with both NiMH (main product for Makita) and NiCd batteries (main product for Dewalt); almost all new professional power tools from Bosch are sold with NiMH. To the Do-It-Yourself market in Denmark, Bosch sells power tools with NiCd and Li-ion batteries, and Black & Decker (who also sells the Dewalt brand) sells only NiCd-driven power tools (based on authors observations and telephone interviews with the companies in question). Hitachi, selling professional power tools, sells only NiMH-driven power tools (only a few older models on their way out have NiCd's).

Based on telephone interviews made in this study with consumer service contacts of the dominating high brand power tools producers represented in Denmark, there are distinct differences in the recommendations of NiMH versus NiCd among the companies:

Makita, who only sell professional powertols, recommends NiMH batteries for the following reasons:

- Larger battery capacities

- No NiCd tax (in Denmark and Sweden)
- No memory effect - batteries can be charged partially with no adverse effect on the battery

See also Makita's answers to a number of questions regarding NiMH performance and characteristics in appendix 3.

On the aspect of larger capacity of NiMH versus lower number of cycles, Makita stated that "the total mileage of NiMH batteries is higher during battery life time, even though NiCds can have the tank filled more times".

Bosch recommends NiMH to professionals for the following reasons:

- Larger battery capacities
- No memory effect - batteries can be charged partially with no adverse effect on the battery

Bosch recommends NiCd batteries to private consumers, because NiCd's regain full capacity with fewer recharges than NiMH's after some months of inactivity (capacity loss due to self-discharge; private consumers do often not use their power tools on a regular basis).

Dewalt (sold by Black & Decker) recommends NiCd to professionals, principally due to poorer temperature performance of NiMH batteries. Hilti and Hitachi sell almost exclusively NiMH to professionals on the Nordic market today.

Li-ion batteries - a new substitute for NiCd

Li-ion is a rechargeable battery type now widely used in consumer electronics. Li-ion is the latest development in the pursuit of a high capacity per battery weight for many portable consumer electronics. Bosch introduced a small (3,6 V) cordless power tool with Li-ion batteries in 2003.

7.2 Charging cycles and battery life

NiMH batteries may have higher total work capacity during the full life time of the battery.

In order to inform the issue of charging cycles versus battery life, the dominating professional power tools producers in Denmark and Norway were interviewed on the telephone. The response to the following question for NiCd and NiMH-driven power tools respectively, from the contacted companies are given in table 7.2.1:

- How many times can a 12V NiCd/NiMH battery for a professional cordless power tool typically be recharged (with a typical charger)?
- And what is the maximum number of recharges that can be made:

- with a typical charger?
- with the best possible charger?

Note that the intention was to observe what would be the typical answer to the question, and not to provide well considered scientific test evidence. The answers vary somewhat between brands, this is however not a focus point here (besides product quality, this may be influenced by company information policies, etc.); the main object of interest here is the difference in charging cycles between NiCd and NiMH batteries.

Table 7.2.1 Results of interviews with major power tools brands in Denmark about attainable charging cycles in the life time of a 12V NiCd and a 12V NiMH battery in power tools - see explanation in text above.

Product (professional series only)	NiCd - <u>typical</u> cycles attainable	NiMH - <u>typical</u> cycles attainable	NiCd - <u>maximum</u> cycles attainable	NiMH - <u>maximum</u> cycles attainable
Makita	1000	750-800		800
Bosch	1000	700-800	1500	800-900
Dewalt	1000-1200	600-800	3000*	1200
Hitachi	1000	1000		
Hilti	300-400			1000**

Notes:
 * In laboratory test only.
 **Unclear in answer from Hilti if 1000 cycles refer to typical or maximum cycles

A calculated example of battery life versus cycles

In the boxes below two examples are calculated to illustrate the relation between battery capacity, recharging cycles and total capacity over the battery life time for professional cordless power tools.

Example 1 illustrate that for realistic voltages, battery capacities, and recharging cycles for a 12 Volt power tool, the NiMH batteries may have higher total work capacity during the full life time of the battery.

Example 2 use the same set of numbers to illustrate that in order to obtain the same work as from a NiCd battery over its life time, the NiMH battery would only have to stand 670 recharging cycles; that is slightly less than the typical cycles estimates provided by NiMH market leaders in Nordic countries Makita and Bosch (table 9-1).

It should be noted that other factors such as partial recharges and self-discharge may influence the actual usable life time capacity of both battery types.

The examples indicate however, that the choice of battery type does not significantly influence the total consumption - and thereby the waste tonnage generated - of professional cordless power tools.

Example 5: Life time capacity with typical parameter values

Typical battery capacities, pro power tools, shop observations in DK 2004.				
NiCd	2	Ah		
NiMH	3	Ah		
Typical cycles, pro power tools, interviews 2004				
NiCd	1000	Cycles		
NiMH	750	Cycles		
Voltage in example				
NiCd	12	Volt		
NiMH	12	Volt		
Calculated battery effect per full cycle (Volt * Ah):				
NiCd	24	Wh/cycle		
NiMH	36	Wh/cycle		
Calculated total effect over battery life, if all capacity is used (Wh/cycle * cycles):				
NiCd	24000	Wh	100%	
NiMH	27000	Wh	113%	of NiCd capacity

Example 6: Break even cycle number for NiMH at equal life time capacity

Typical battery capacities, pro power tools, shop observations in DK 2004.				
NiCd	2	Ah		
NiMH	3	Ah		
Voltage in example				
NiCd	12	Volt		
NiMH	12	Volt		
Calculated battery effect per full cycle (Volt * Ah):				
NiCd	24	Wh/cycle		
NiMH	36	Wh/cycle		
Total effect over battery life, if all capacity is used (Wh/cycle * cycles):				
NiCd	24000	Wh		
Total effect over battery life equal to 100% of NiCd capacity				
NiMH	24000	Wh (constant in this example)		
Typical cycles, pro power tools, interviews 2004				
NiCd	1000	Cycles		
Cycles at break even with NiCd life time capacity (with NiCd at 1000 cycles); (Wh in battery life divided by Wh/cycle):				
NiMH	670	Cycles		

No Name cordless power tools

NiMH batteries in Do-It-Yourself cordless power tools, today mainly No Name machines, is less well understood. Data in typical recharging cycles for No Name cordless power tools have not been collected for this

study, and may likely be more difficult to obtain. For these products, the consumers go for the low price rather than battery performance. For this product group as a whole the total usable battery capacity over its life time may likely be governed more by the general quality of the machines than by the type of battery used. It is therefore difficult to say something about any differences in consumption and waste generation between battery types for these products.

7.3 Self-discharge

Bosch recommends NiCd batteries to private consumers, because NiCd's regain full capacity with fewer recharges than NiMH's after some months of inactivity (capacity loss due to self-discharge; private consumers do often not use their power tools on a regular basis).

In Bosch's general information material about batteries in cordless power tools, advice is given that when battery capacity has fallen due to inactivity for a period, the batteries should be charged and discharged completely a couple of times to regain full capacity. There is however no distinction between NiCd and NiMH as regards this aspect in the booklet (Bosch,1999).

7.4 Temperature performance

In *Bosch's* general information booklet about batteries in cordless power tools, the following is mentioned for NiMH batteries: They do not function at temperatures below -10 degrees Celsius, but are not harmed by low temperatures and will function normally, when normal working temperatures are attained.

Therefore Bosch recommends that the battery is kept in an inner pocket, during inactive periods when working at frost degrees. Similar advice is not given for NiCd batteries in the same booklet (Bosch, 1999). The booklet represents state of the art in 1999. In the telephone interviews with Bosch, they state that battery performance is poor at temperatures below 0 degrees Celsius for both NiCd and NiMH, and no information is given on this aspect in their user manuals. NiMH battery cells with improved performance at high temperatures are under development according to Bosch.

Dewalts user manual for a series of 12V NiCd and NiMH cordless power tools do not have differences in recommendations for NiMH's and NiCd's. For both types the manual states that recharging should not take place at temperatures below 4 degrees and above 40 degrees Celsius; no recommendations on temperatures at discharge are given.

Makita stated in a telephone interview that they observe no differences between NiMH and NiCd at low temperatures. Optimal charging temperatures are between 5 and 30 degrees Celsius. Makita's chargers can however, according to the company, also charge the batteries at temperatures below 0 degrees Celsius.

7.5 Battery prices

NiMH battery nominal prices are higher per cell than NiCd, but the prices of NiMH will likely fall as production volume rise. The higher capacity partly outbalance the higher NiMH prices. NiMH sometimes have a lower price/capacity factor. As regards battery effect over the full life time of the battery unit, the NiMH batteries would likely be only slightly more expensive than NiCd

NiMH battery nominal prices are still higher per cell for cordless power tools use, according to industry sources. As seen for NiMH batteries for other uses (consumer electronics etc.), the prices of NiMH batteries for cordless power tools will likely fall as production volume rise. When taking the battery capacity into account, the higher capacity partly outbalance the higher NiMH prices, as illustrated in the examples below.

Examples of consumer prices for comparable NiCd and NiMH battery units for cordless power tools were sought on the Internet. Price data were compiled from three sites; one offering original battery units, and two offering copy battery units tailor-made for specific cordless power tools. Selected examples are shown in table 9-2 (and many more examples are given in appendix 2). In most cases NiMH battery units are more expensive than similar NiCd units. Besides the actual price, the table shows the price in percent of the price of the cheapest NiCd battery unit for each machine. Note that the prices are consumer prices; the basis for the price setting is not known, but it may include other factors than production costs.

When taking the working time per recharge (battery capacity per recharge cycle) into account by dividing the price with the battery capacity, NiCd and NiMH are much more equal and NiMH sometimes have a lower price/capacity factor. The table also shows the price/capacity relation in percent of the price/capacity relation for the cheapest NiCd for a specific cordless power tool, for easier comparison.

As regards battery effect over the full life time of the battery unit, the NiMH batteries would likely be only slightly more expensive than NiCd at current price levels, based on the calculation examples made in section 7.2.

As regards the charging units for power tool batteries, these are always supplied as part of the power tool sales package, but can also be bought separately. Based on observations in retailer shops in Denmark,

many charging units from professional power tools producers that supply both NiCd and NiMH batteries to their tools, are today capable of charging both types of batteries. No data on production costs for charging units were collected for this study.

Table 7.2 Examples of prices for NiCd and NiMH battery units for cordless power tools, and their relations across battery type.

Product brand	Battery type	Volt	Capacity (Ah)	Price (£)	100 *Price /mAh	% of price of cheapest NiCd	Price/capacity in % of cheapest NiCd price/capacity	Notes
Hitachi EB24B	NiCd	24	2	146.99	7.3	100	100	1
Hitachi EB2430H	NiMH	24	3	153.34	5.1	104	70	1
Bosch 2 607 335 210(or 264)	NiCd	14.4	2	76.67	3.8	100	100	1
Bosch 2 607 335 246(or 418)	NiMH	14.4	2	95.84	4.8	125	125	1
Bosch 2 607 335 252	NiMH	14.4	2.8	136.43	4.9	178	127	1
Dewalt De9062	NiCd	9.6	1.25	42	3.4	100	100	1
Dewalt De9061	NiMH	9.6	2	58.75	2.9	140	87	1
DeWalt DE9085	NiMH	9.6	2	59.93	3.0	143	89	1
Dewalt DE9074	NiCd	12	1.3	31.73	2.4	100	100	1
Dewalt De9071	NiMH	12	2	64.98	3.2	205	133	1
Bosch B2300	NiCd	12	1500	38.16	2.5	100	100	2
"	NiCd	12	2000	52.03	2.6	136	102	2
"	NiMH	12	2200	62.44	2.8	164	112	2
"	NiMH	12	3000	74.93	2.5	196	98	2
Dewalt 246536	NiCd	9.6	1500	18.18	1.2	100	100	2
"	NiCd	9.6	2000	27.29	1.4	150	113	2
"	NiMH	9.6	2200	31.24	1.4	172	117	2
"	NiMH	9.6	3000	36.45	1.2	200	100	2
Makita 4190DW	NiCd	9.6	1500	31.16	2.1	100	100	2
"	NiCd	9.6	2000	25.67	1.3	82	62	2
"	NiMH	9.6	2200	29	1.3	93	63	2
"	NiMH	9.6	3000	34.44	1.1	111	55	2
Makita DK1016DL	NiCd	18	2000	30.39	1.5	100	100	2
"	NiMH	18	2200	35.92	1.6	118	107	2
Blach&Decker PS130	NiCd	12	1500	40.95	2.7	100	100	3
"	NiMH	12	3000	69.3	2.3	169	85	3
Bosch B2300, B3300K, 3305K,3310K, 3315K, 3500	NiCd	12	1500	35.9	2.4	100	100	3
"	NiMH	12	3000	61.25	2.0	171	85	3
Dewalt 9072	NiCd	12	1500	39.4	2.6	100	100	3
"	NiMH	12	3000	59.5	2.0	151	76	3
Makita 1222	NiCd	12	2000	45.5	2.3	100	100	3
Makita 1233	NiMH	12	2200	56	2.5	123	112	3

Notes:

1: Original batteries at www.kelkoo.co.uk; 2004.

2: Copy batteries at www.globalbatteries.co.uk; 2004.

3: US dollars; copy batteries at www.batteryprice.com; 2004

References

Bosch (1999): Battery information booklet. Submitted from Robert Bosch, Denmark, November 2004.

Maag, Jakob and Hansen, Charlotte Libak (2004): Collection potential for nickel-

cadmium batteries in Denmark. COWI for the Danish EPA, September 2004 draft, Copenhagen.

Appendix 1

Summary of national statistics (Eurostat)

Net import is calculated as import minus export. No production of cordless power tools takes place in the countries mentioned.

National statistics from Norway and Iceland are grouped with other electrical hand tools for net-connection, and are therefore of little relevance.

Table 1 Net. import of cordless power tools

	2003	2002	2001	2000	1999
Denmark	461,074	423,694	134,397	132,286	72,109
Sweden	566,142	329,082	403,635	312,414	146,778
Finland	192,794	241,199	211,439	307,707	223,209

Table 2 Net. import of cordless power tools/1.000 inhabitants

	2003	2002	2001	2000	1999
Denmark	85	87	25	25	13
Sweden	63	37	45	35	16
Finland	37	46	41	59	43

Notes: Figures above are sum of results for the CN-numbers 85081010, 84672110, 85088030 and 84672930: 85081010 (years 1999-2001) and 84672110 (years 2002-2003) cover identical items: DRILLS OF ALL KINDS FOR WORKING IN THE HAND, WITH SELF-CONTAINED ELECTRIC MOTOR CAPABLE OF OPERATION WITHOUT AN EXTERNAL SOURCE OF POWER. 85088030 (years 1999-2001) and 84672930 (2002-2003) cover identical items: ELECTRO-MECHANICAL TOOLS FOR WORKING IN THE HAND, WITH SELF-CONTAINED ELECTRIC MOTOR CAPABLE OF OPERATION WITHOUT AN EXTERNAL SOURCE OF POWER (EXCL. THOSE FOR WORKING TEXTILE MATERIALS, SAWS AND DRILLS)
Source: Eurostat website, 2004

Appendix 2

Examples of prices for battery units for cordless power tools

Copy batteries at www.globalbatteries.co.uk; 2004.

Product brand	Battery type	Volt	mAh	Price (£)	100*Price /mAh	1000*Price /mAh*V
Bosch B2300	NiCd	12	1500	38.16	2.5	2.1
"	NiCd	12	2000	52.03	2.6	2.2
"	NiMH	12	2200	62.44	2.8	2.4
"	NiMH	12	3000	74.93	2.5	2.1
Bosh GSR	NiCd	7.2	1500	31.04	2.1	2.9
"	NiCd	7.2	2000	27.16	1.4	1.9
"	NiMH	7.2	2200	29.1	1.3	1.8
"	NiMH	7.2	3000	34.92	1.2	1.6
" GSR 9.6	NiCd	9.6	1300	24.43	1.9	2.0
"	NiCd	9.6	2000	28.2	1.4	1.5
"	NiMH	9.6	2200	30.08	1.4	1.4
"	NiMH	9.6	3000	33.83	1.1	1.2
Craftsman 11333	NiCd	14.4	1400	26.22	1.9	1.3
"	NiCd	14.4	2000	33.88	1.7	1.2
"	NiMH	14.4	2200	42.46	1.9	1.3
"	NiMH	14.4	3000	52.59	1.8	1.2
" 27466	NiCd	13.2	1500	26.7	1.8	1.3
"	NiCd	13.2	2000	40.06	2.0	1.5
"	NiMH	13.2	2200	46.72	2.1	1.6
"	NiMH	13.2	3000	53.42	1.8	1.3
" 27487	NiCd	12	1500	25.35	1.7	1.4
"	NiCd	12	2000	35.54	1.8	1.5
"	NiMH	12	2200	50.67	2.3	1.9
"	NiMH	12	3000	60.09	2.0	1.7
" 315.221890	NiCd	9.6	1500	17.13	1.1	1.2
"	NiCd	9.6	2000	24	1.2	1.3
"	NiMH	9.6	2200	18.03?		
"	NiMH	9.6	3000	18.03?		
" 315.222780	NiCd	9.6	1500	17.13	1.1	1.2
"	NiCd	9.6	2000	24	1.2	1.3
"	NiMH	9.6	2200	29.47	1.3	1.4
"	NiMH	9.6	3000	34.28	1.1	1.2
" 315.224110	NiCd	12	1500	26.46	1.8	1.5
"	NiCd	12	2000	39.69	2.0	1.7

Product brand	Battery type	Volt	mAh	Price (£)	100*Price /mAh	1000*Price /((mAh*V))
"	NiMH	12	2200	44.99	2.0	1.7
"	NiMH	12	3000	52.92	1.8	1.5
" 315224530	NiCd	13.2	1500	21.61	1.4	1.1
"	NiCd	13.2	2000	30.24	1.5	1.1
"	NiMH	13.2	2200	34.56	1.6	1.2
"	NiMH	13.2	3000	35	1.2	0.9
" 315228900	NiCd	18	2000	26.7	1.3	0.7
"	NiMH	18	2200	33.15	1.5	0.8
"	NiMH	18	3000	40.15	1.3	0.7
" 97322489	NiCd	16.8	1700	21.42	1.3	0.8
"	NiCd	16.8	2000	25.36	1.3	0.8
"	NiMH	16.8	2200	30.17	1.4	0.8
"	NiMH	16.8	3000	37.72	1.3	0.7
Dewalt 246536	NiCd	9.6	1500	18.18	1.2	1.3
"	NiCd	9.6	2000	27.29	1.4	1.4
"	NiMH	9.6	2200	31.24	1.4	1.5
"	NiMH	9.6	3000	36.45	1.2	1.3
" 25453	NiCd	12	1500	15.43	1.0	0.9
"	NiCd	12	2000	23.37	1.2	1.0
"	NiMH	12	2200	25.72	1.2	1.0
"	NiMH	12	3000	29.12	1.0	0.8
" DE9095	NiMH	18	2200	38.11	1.7	1.0
"	NiMH	18	3000	47.54	1.6	0.9
" DW	NiCd	14.4	1500	20.13	1.3	0.9
"	NiCd	14.4	2000	26.42	1.3	0.9
"	NiMH	14.4	2200	31.93	1.5	1.0
"	NiMH	14.4	3000	36.36	1.2	0.8
" DW908	NiMH	18	2200	38.97	1.8	1.0
"	NiMH	18	3000	57.64	1.9	1.1
" DW920	NiCd	7.2	1500	17.49	1.2	1.6
"	NiCd	7.2	2000	25.36	1.3	1.8
"	NiMH	7.2	2200	26.23	1.2	1.7
"	NiMH	7.2	3000	33.23	1.1	1.5
Makita 4190DW	NiCd	9.6	1500	31.16	2.1	2.2
"	NiCd	9.6	2000	25.67	1.3	1.3
"	NiMH	9.6	2200	29	1.3	1.4
"	NiMH	9.6	3000	34.44	1.1	1.2
" 6012DL	NiCd	7.2	1500	17.41	1.2	1.6
"	NiCd	7.2	2000	26.11	1.3	1.8
"	NiMH	7.2	2000	30.96	1.5	2.2
"	NiMH	7.2	3000	40.18	1.3	1.9
" 6222D	NiCd	9.6	1500	23.92	1.6	1.7
"	NiCd	9.6	2000	28.78	1.4	1.5
"	NiMH	9.6	2200	35.78	1.6	1.7
"	NiMH	9.6	3000	38.71	1.3	1.3
" DK1016DL	NiCd	18	2000	30.39	1.5	0.8

Product brand	Battery type	Volt	mAh	Price (£)	100*Price /mAh	1000*Price / (mAh*V)
"	NiMH	18	2200	35.92	1.6	0.9
Ryobi CTH1201	NiCd	12	1400	26.58	1.9	1.6
"	NiCd	12	2000	36.74	1.8	1.5
"	NiMH	12	2200	40.88	1.9	1.5
"	NiMH	12	3000	48.29	1.6	1.3
" " grey	NiCd	12	1400	26.58	1.9	1.6
"	NiCd	12	2000	35.44	1.8	1.5
"	NiMH	12	2200	40.49	1.8	1.5
"	NiMH	12	3000	51.25	1.7	1.4
" CTH 1442	NiCd	14.4	1400	26.36	1.9	1.3
"	NiCd	14.4	2000	41.02	2.1	1.4
"	NiMH	14.4	2200	44.57	2.0	1.4
"	NiMH	14.4	3000	52.74	1.8	1.2
" CTH 962	NiCd	9.6	1500	17.12	1.1	1.2
"	NiCd	9.6	2000	23.97	1.2	1.2
"	NiMH	9.6	2200	28.26	1.3	1.3
"	NiMH	9.6	3000	34.25	1.1	1.2
" HP721	NiCd	7.2	1500	15.42	1.0	1.4
"	NiCd	7.2	2000	22.26	1.1	1.5
"	NiMH	7.2	2200	25.69	1.2	1.6
"	NiMH	7.2	3000	32.54	1.1	1.5

Copy batteries at www.batteryprice.com; 2004

Produktmærke	Batteritype	Volt	mAh	Pris (\$)	100*Price /mAh	1000*Price / (mAh*V)
Black & Decker PS120	NiCd	9.6	1500	36.75	2.5	2.6
"	NiMH	9.6	3000	60.9	2.0	2.1
PS130	NiCd	12	1500	40.95	2.7	2.3
"	NiMH	12	3000	69.3	2.3	1.9
PS140	NiCd	14.4	1700	49.35	2.9	2.0
"	NiMH	14.4	3000	77.7	2.6	1.8
PS145	NiMH	18	3000	93.45	3.1	1.7
Bosch B2300. B3300K. 3305K.3310K. 3315K. 3500	NiCd	12	1500	35.9	2.4	2.0
"	NiMH	12	3000	61.25	2.0	1.7
DeWalt DW9062	NiCd	9.6	1500	35.9	2.4	2.5
"	NiMH	9.6	3000	56	1.9	1.9
DW9072	NiCd	12	1500	39.4	2.6	2.2
"	NiMH	12	3000	59.5	2.0	1.7
DW9094	NiCd	14.4	1500	46.4	3.1	2.1
"	NiMH	14.4	3000	70	2.3	1.6
DW9096	NiCd	18	1500	42	2.8	1.6
"	NiMH	18	3000	83.15	2.8	1.5
Makita 1222	NiCd	12	2000	45.5	2.3	1.9

Produktmærke	Batteritype	Volt	mAh	Pris (\$)	100*Price /mAh	1000*Price /((mAh*V))
Makita 1233	NiMH	12	2200	56	2.5	2.1
Makita 1422	NiCd	14.4	2000	57.75	2.9	2.0
Makita 1433	NiMH	14.4	2200	56.90		
Makita 1822	NiCd	18	2000	61.25	3.1	1.7
Makita 1833	NiMH	18	2200	63.9	2.9	1.6
Ryobi 1400669	NiCd	9.6	1500	37.65	2.5	2.6
"	NiMH	9.6	3000	57.75	1.9	2.0
1400652	NiCd	12	2000	54.25	2.7	2.3
"	NiMH	12	2000	70		
1400671	NiCd	14.4	2000	57.75	2.9	2.0
"	NiMH	14.4	3000	77	2.6	1.8

Original batteries at www.kelkoo.co.uk; 2004

Product brand	Battery type	Volt	Ah	Price (£)	100*Price /mAh	1000*Price /((mAh*V))
Hitachi EB7	NiCd	7.2	1.3	42.3	3.3	4.5
Hitachi EB9S	NiCd	9.6	1.4	44.42	3.2	3.3
Hitachi EB930H	NiMH	9.6	2	76.14	3.8	4.0
Hitachi EB12S	NiCd	12	1.4	51.82	3.7	3.1
Hitachi EB12M	NiCd	12	2	94.12	4.7	3.9
Hitachi EB1239H	NiMH	12	?	90.7		
Hitachi EB14S	NiCd	14.4	1.4	72.97	5.2	3.6
Hitachi EB24B	NiCd	24	2	146.99	7.3	3.1
Hitachi EB2430H	NiMH	24	3	153.34	5.1	2.1
Dewalt De9064	?	7.2	1.25	32	2.6	3.6
Dewalt De9062	?	9.6	1.25	42	3.4	3.5
Dewalt De9061	NiMH	9.6	2	58.75	2.9	3.1
DeWalt DE9085	NiMH	9.6	2	59.93	3.0	3.1
DeWalt DE9037	NiMH	12	3	61.67	2.1	1.7
Dewalt DE9074	?	12	1.3	31.73	2.4	2.0
DeWalt DE9071	?	12	2	42.3	2.1	1.8
Dewalt De9071	NiMH	12	2	64.98	3.2	2.7
DeWalt DE9087	?	14.4	3	87.24	2.9	2.0
DeWalt DE9094	?	14.4	1.3	35.24	2.7	1.9
Dewalt De9091	NiMH	14.4	2	76.98	3.8	2.7
DeWalt DE9098	?	18	1.3	41.13	3.2	1.8
Dewalt De 9095	NiMH	18	2	88	4.4	2.4
DeWalt DE9039	NiMH	18	3	94.29	3.1	1.7
Makita 193889-4	NiMH	9.6	2.6	43.62	1.7	1.7
Makita 193101-2	NiMH	14.4	2.6	73	2.8	1.9
Makita (til 8443DWA)	NiCd	18	2	73	3.7	2.0
Makita 193127-4	NiMH	24	1.7	118.97	7.0	2.9
Bosch 2 607 335 072	NiCd	9.6	1.7	58.16	3.4	3.6
Bosch 2 607 335 542	NiCd	12	1.3	57.28	4.4	3.7

Product brand	Battery type	Volt	Ah	Price (£)	100*Price /mAh	1000*Price /((mAh*V)
Bosch 2 607 335 430	NiCd	12	2.4	80.42	3.4	2.8
Bosch 2 607 335 210(or 264)	NiCd	14.4	2	76.67	3.8	2.7
Bosch 2 607 335 246(or 418)	NiMH	14.4	2	95.84	4.8	3.3
Bosch 2 607 335 252	NiMH	14.4	2.8	136.43	4.9	3.4
Bosch 2 607 335 278	NiCd	18	1.3	83.72	6.4	3.6
Bosch 2 607 335 268	NiCd	24	2	123	6.2	2.6
Makstar (BH2420)	NiMH	24	2	125	6.3	2.6
Makstar (BH2430)	NiMH	24	3	171	5.7	2.4
Makstar (BH2433)	NiMH	24	3.3	175	5.3	2.2

Appendix 3

Information from power tools producer Makita

Questions & Answers NiMH / NiCd between

The German Federal Environmental Agency

and:

– **Makita, Mr. Nalbach** –

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(English translation: Online translator and proofreading / correction by Silke Karcher)

For the comparison NiMH/NiCd we represented the difference on basis of our products.

1. Cycle firmness / number of charging cycles: Comparison NiMH/NiCd

→ During the conventional charging control NiMH has a shorter life span than NiCd.

The NiMH-system of Makita with our own charging technology reaches 50% more charging cycles than the NiCd.

2. Total capacity over the lifetime, with consideration of capacity AND No. of cycles.

→ During the normal charging control NiMH has more total capacity despite smaller number of cycles than NiCd, since NiMH has a higher capacity than NiCd.

Makita-NiMH reaches 50% more total capacity because of longer life span in the comparison with NiCd (2,0Ah). In addition, in the future this difference will continue to increase due to the higher capacity of NiMH.

3. Behavior at Very low temperature

Starting from which temperature do the two systems not function any longer? Does the problem only occur when the equipment is *stored* at low temperature, or even if “warm” equipment is used at low temperature?

→ If the accumulator (stored at ambient temperature) is used at low temperatures, the accumulator functions problem-free. Only if the accumulator is stored at low temperatures and the cell temperature has fallen to very low values, the accumulator cannot work any longer satisfyingly.

At temperatures $\geq 0^{\circ}\text{C}$ problems do not occur.

Below 0°C : the larger the working load (the discharge electric current) is, the stronger is the effect of the temperature difference. For example: with high working load (discharge current) NiCd still operates at -20°C , NiMH could stop working satisfyingly at -5°C (This means: weak torque, bad performance due to voltage drop). If one continues to work despite the bad performance, the cells warm up and a temperature compensation occurs. This concerns the cell temperature.

4. Charging behavior at low temperatures

Is only discharge performance a problem or does the recharging also represent a problem?

→ During normal charging control, low temperatures cause a shorter life span (No. of charge/recharge cycles) with both systems. With our technology the battery charger can avoid the reduction of the life span.

5. Storage

NiMH deteriorate/ become un-functionable with long storage. When does this effect occur? a) originally charged b) originally uncharged battery?

In which time intervals one would have to recharge, in order to prevent damage?

→ NiMH accumulators do not get broken with long storage. Partly the capacity can be reduced with NiMH-systems depending on their construction. If the accumulator is stored after “over”-discharging (100% discharge) some time (depending upon ambient temperature differently), these effects can occur.

- A) Originally charged: At ambient temperature up to 2.5 years no capacity reduction.
- B) Originally uncharged: At ambient temperature up to 6 months no capacity reduction.

Before storage one should charge NiMH. If the accumulator is charged after 2.5 years, the capacity is not reduced.

6. MEMORY effect in comparison to NiMH/NiCd

The so-called MEMORY effect generally is very rare for NiMH, but it does occur. Makita prevents the MEMORY effect with the optionally available refreshing adapter, which has an automatic revitalization/ refreshing function.

7. Differences in prices NiMH/Ni-Cd, including consideration of the charging technology.

The NiMH-accumulator is today still more expensive than NiCd. But if the total capacity / work until the end of the life span is calculated, the operating cost is more favorable than with the NiCd-system: