TOTAL COST of OWNERSHIP (TCO)

Cost Analysis of Total Investment for a Data Centre

This paper shows improved methods for determining, predicting and measuring the Total Cost of Ownership (TCO) for a data centre, and defines the individual expense factors.
The biggest contribution to the total cost is usually an oversized UPS system or an inefficient one.

Introduction

In making a decision to purchase or to invest, it is important to measure the Total Cost of Ownership (TCO) in order to predict how the investment will be paid back (RETURN-ON-INVESTMENT - ROI).

This paper will describe a methodology for determining the individual cost factors involved in protecting the investment of a data centre such as the necessary infrastructure for providing power, cooling and IT equipment protection (but not the cost of the IT equipment itself).

To demonstrate, let's take the example of a data centre with an 80kVA load requirement, where we will describe the cost factors of the UPS system investment. We will presume that 100% of the 80kVA load is required (in the case where less load would be required, for example only 50% (40 kVA), the indications that follow would be even worse).

Total cost of investment of a UPS system depends not only on the purchase price but on other factors too.

Basically, we can differentiate the costs into 4 major categories:

- **Capital Cost**
  - Purchase price
  - Transportation cost (determined by weight and volume)
- **Building Cost / Floor Cost**
  - Installation cost
  - Power density (kVA /sq m)
  - Security Concept (Redundancy, Availability)
- **Operating Cost**
  - Energy expenses related to UPS losses (technology-dependent)
  - Additional energy expenses for cooling systems (expenditures for the cooling of additional losses)
  - Maintenance cost
  - Spare parts stock, logistics and handling
  - Training cost of maintenance people
- **Upgrade Cost**
  - Upgrade costs (flexibility, upgrading without load-interruption)

Case study:
Comparison between a Traditional Parallel -Configuration 2 x 80kVA and a Advanced Modular Parallel – Configuration 3 x 40kVA.

Let's take the example of a UPS system with a total load of 80kVA, where we will compare the total costs and performance of a traditional UPS system with those of a advanced modular UPS system. We assume that for increased availability reasons, a parallel redundant solution (n+1) is selected.

Load: 80kVA	UPS - Design	UPS Configuration	Battery
Traditional System		Parallel System 2 x 80 KVA (1+1) Redundant	Batteries are mounted in an external Cabinet
Modular System		Parallel System 3 x 40 KVA (2+1) Redundant	Batteries are mounted in an external Cabinet

Capital Cost

Purchase price:

The purchase price of a traditional UPS system is approximately 20-25% cheaper than that of an advanced modular UPS system. The purchase price is NOT, however, the only decisive factor when considering the overall costs. The cheaper purchase price of traditional UPS technology, but with its significantly higher operating costs, when compared to the **higher purchase price** of a **MODULAR SYSTEM** whose technology allows for the reduction of energy loss expenditures, are already compensated for within its **first year of operation**.

There are additional long term costs to consider, and they also speak in favour of MODULAR TECHNOLOGY. In the following paragraphs, clear differences will be shown between the two technologies so that they can be judged individually.

Transport cost dependent on Weight and Volume:

A traditional UPS is usually built with an output transformer, which increases the total weight up to 2- 3 times compared to that of a transformer-less UPS system. This weight difference directly influences the cost of transport. This increased transport cost can be up to 50% more.

System (80KVA, n+1)	Weight of transport (kg)	Volume of transport (m3)	Cost of transport (%)
Traditional System	approx. 800 kg	B x T x H = 2x(90x80x190)cm = **2.75 m3**	150%
Modular System	approx. 325 kg	B x T x H = 55x75x180cm = **0.75 m3**	100%

Building Cost / Floor Cost

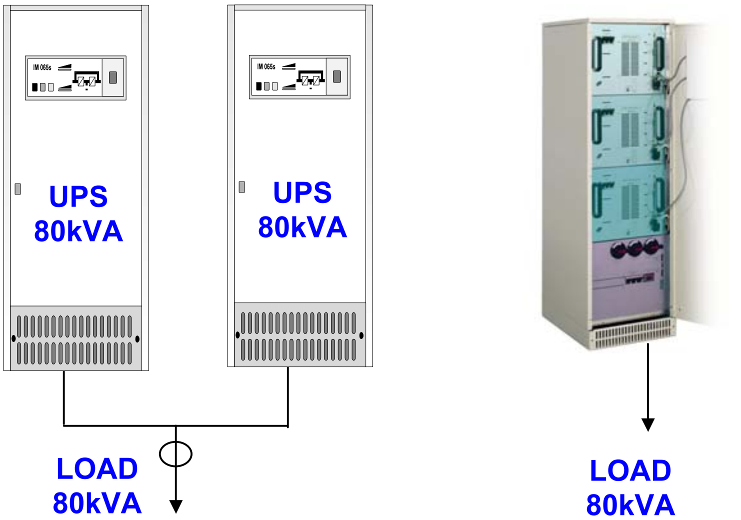
Installation costs and Power in kVA / footprint surface:

The traditional UPS system (2 basic systems) needs more space for the installation (usually twice as much surface in m^2) compared with a modular concept UPS system.

System (80KVA, n+1)	Foot print m^2	KVA / m^2	Cost of installation (%)
Traditional System	B x T: 2x(90x80) cm = **1.44 m^2**	160kVA/1.44 m^2=**111**	150%
Modular System	B x T: 55x75 cm = **0.42 m^2**	120kVA/0.42 m^2= **285**	100%

Security Concept (Redundancy, Availability):

In comparing equivalent UPS systems, the availability is dependent on the MTBF factor (MEAN TIME BETWEEN FAILURE) but is even more dependent on quick repair time in cases of failure, also known as the MTTR factor (MEAN TIME TO REPAIR). In modular UPS systems, the shorter MTTR value can be up to 12 times less compared to traditional UPS systems, due to the fact that the modular system allows for quick module exchange without load interruption. This has the effect of a quicker repair time, increasing the total availability (A) of the UPS system (A=0.999999).



Example 1	NON Modular (1+1) Redundant Configuration	Modular (2+1) Redundant Configuration
MTBF	1'250'000	830'000
MTTR	6h	6h
Availability (A)	0,9999950 (5 Nine)	0,9999920 (5 Nine)

Example 2	NON Modular (1+1) Redundant Configuration	Modular (2+1) Redundant Configuration
MTBF	1'250'000	830'000
MTTR	6h	0.5h
Availability (A)	0,9999950 (5 Nine)	0,9999990 (6 Nine)

$$\text{Availability (A)} : = MTBF_{UPS} / (MTBF_{UPS} + MTTR_{UPS})$$

Operation Cost

<u>Energy costs to cover the UPS losses (technology dependent) / Additional energy costs for cooling (expenditures for additional losses of the cooling systems involved)</u>

Energy costs are directly proportional to a complete system's efficiency working at a defined load. The UPS systems do not work generally under ideal circumstances of 100% load, but rather tend to work under partial load conditions. It is therefore even more important to pay attention to the inner architecture of a UPS system, especially how the system performs and its efficiency under partial load conditions.
Most architecture of mission critical loads are parallel redundant systems sharing 50% of the load per system: this means a lower efficiency at partial loads as opposed to full load conditions.

With the **Modular Concept**, smaller power units are configured in parallel (e.g. 3 small modules instead of 2 big STAND-ALONE systems) to achieve an equal amount of redundancy, but with the advantage of a better performance and **higher efficiency in partial load conditions**.

In our example (80 kVA with redundancy) the load sharing would look like this:

Traditional System:	2x80kVA	Load 80 kVA	<u>Load per Unit</u>:	50%
Modular System:	3x40kVA	Load 80 kVA	<u>Load per Unit</u>:	**<u>66.7%</u>**

Efficiency:

System (80KVA, n+1)	**Efficiency (η) at full load 100%**	**Efficiency (η) at partial load 50%**	**Losses in kW / Load at (%)**
Traditional System	η= 90%	η= 87%	2x4.8KW = **9.6KW** / at 50%, η= 87%
Modular System	η= 95%	η= 92.5%	3x1.6KW = **4.8KW** / at 66.7%, η=0.93

Energy Costs to cover the losses of the UPS and the Cooling systems [1]:

System (80KVA, n+1)	**Energy costs UPS losses within 5 years**	**Additional energy costs Cooling system losses within 5 years**	**Total Energy cost <u>Savings</u> within 5 years**
Traditional System	**2x41'877 Euro** within 5 years at 0.2 Euro/kWh	**2x83'774 Euro** within 5 years at 0.2 Euro/kWh	0
Modular System	**3x14'137** Euro within 5 years at 0.2 Euro/kWh	**3x28'273 Euro** within 5 years at 0.2 Euro/kWh	**124'072 Euro** within 5 years at 0.2 Euro/kWh

Detailed calculations see attachments

[1] See attached calculation sheets

Maintenance cost:

A traditional UPS system with its greater volume and costly construction of single components is much more time consuming as far as maintenance goes than its modular UPS system counterpart. The maintenance costs of a modular system are up to 30% lower compared with a traditional system. Single components of modular systems are smaller, easier to manage and therefore easier to replace.

System (80KVA, n+1)	Maintenance cost	Savings (%)
Traditional System	100 %	0 %
Modular System	70 %	**Typically up to 30 %**

Spare part stock, logistic and spare part exchange

Traditional UPS systems are not built as system-modules and therefore it is very difficult to propose a cost efficient spare part package. For security reasons, often the biggest spare part kit will be chosen, which is inevitably the most expensive one and furthermore, does not guarantee that the spare kit will be effective or have the correct part required for any or all failures which could arise. In addition there is a bigger time investment for stock management, logistics, and management of the spares.

With a modular system and its hot swappable technology, the complications of choosing the right spare part kit is eliminated. All that is required is a single replacement module, even when there are different power rages in operation. Just choose the highest kVA-rated module as your spare, which will be able to cover all the lower power ranges as well.

- **Replace modules even with personnel which have not been specifically trained within 30 minutes**
- **With the least amount of effort, with the smallest footprint and least amount of expenditure!**

Through the use of spare modules, it is possible to save up to 50% on logistics and stock management costs.

System (80KVA, n+1)	Surface of stock in m2	Volume of stock in (m3)	Stock cost (%)
Traditional System	B x T = 200x60 cm = **1.2 m2**	B x T x H = 200x60x0.5 cm = **0.6 m3**	100%
Modular System	B x T = 50x6 cm = **0.34 m2 (1 Module)**	B x T x H = 50x68x40 cm = **0.14 m3 (1 Module)**	Typical 50%

Training cost of maintenance personnel:

If there are many different types of UPS systems within a company, maintenance training for each individual system is time consuming and high in cost as having a good backup of know-how between the service and maintenance people is critical. Modular systems by contrast use many power ranges with the same board layouts and architecture. This means a smaller training investment and respectively, having the know-how of the basic modules can easily be transferred and applied to other UPS models without requiring additional training. It is no longer necessary to have system based specialists, therefore the KNOW-HOW can be spread out on a large scale. **Savings related to the** training costs of maintenance personnel can be **up to 67%.**

Upgrade cost

Upgrade cost (Flexibility, Upgrade without any interruption of Load .....)

Should a traditional UPS need an upgrade in the future, one must calculate the extra space in which to position the additional UPS as well as costly cabling. Consider too, that the existing UPS needs to be shut down in order to perform the upgrade.

With the modular concept, the upgrade is performed by simply inserting the additional power unit(s) (i.e. module(s)) into the rack of a single system cabinet: for example, 3x20 kVA modules may be exchanged with 3x30 kVA modules. The system's distribution and frame must be foreseen to correspond to the maximum requested power.

Such upgrades can be performed without any interruption to the load (HOT SWAPPABLE MODULES) and without any additional work on site. This unique flexibility makes upgrading a system easy and without any significant additional costs.

System Upgrade	Additional foot print (m$^{2)}$	Installation cost (%)
Traditional System	B x T (90x80) cm = **0.72m2**	100%
Modular System	**None**	**Non significant (5-10 %)**

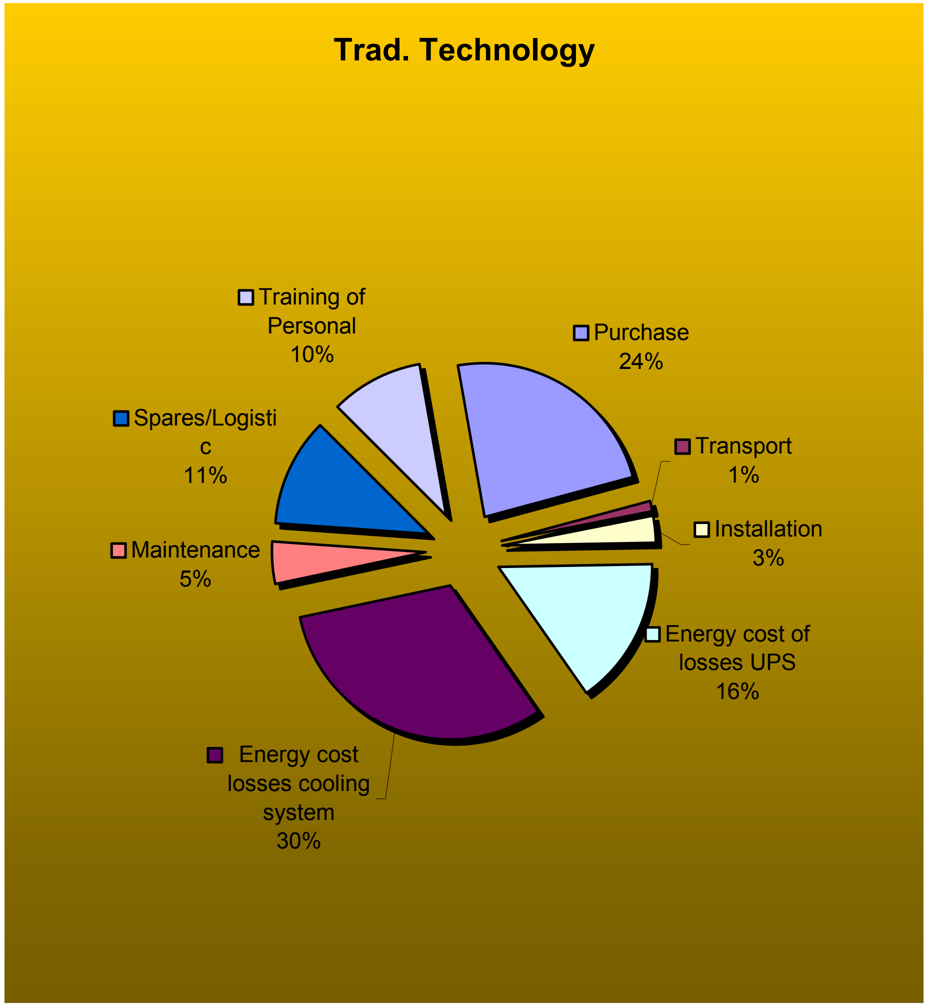
Summary of costs / cost comparison

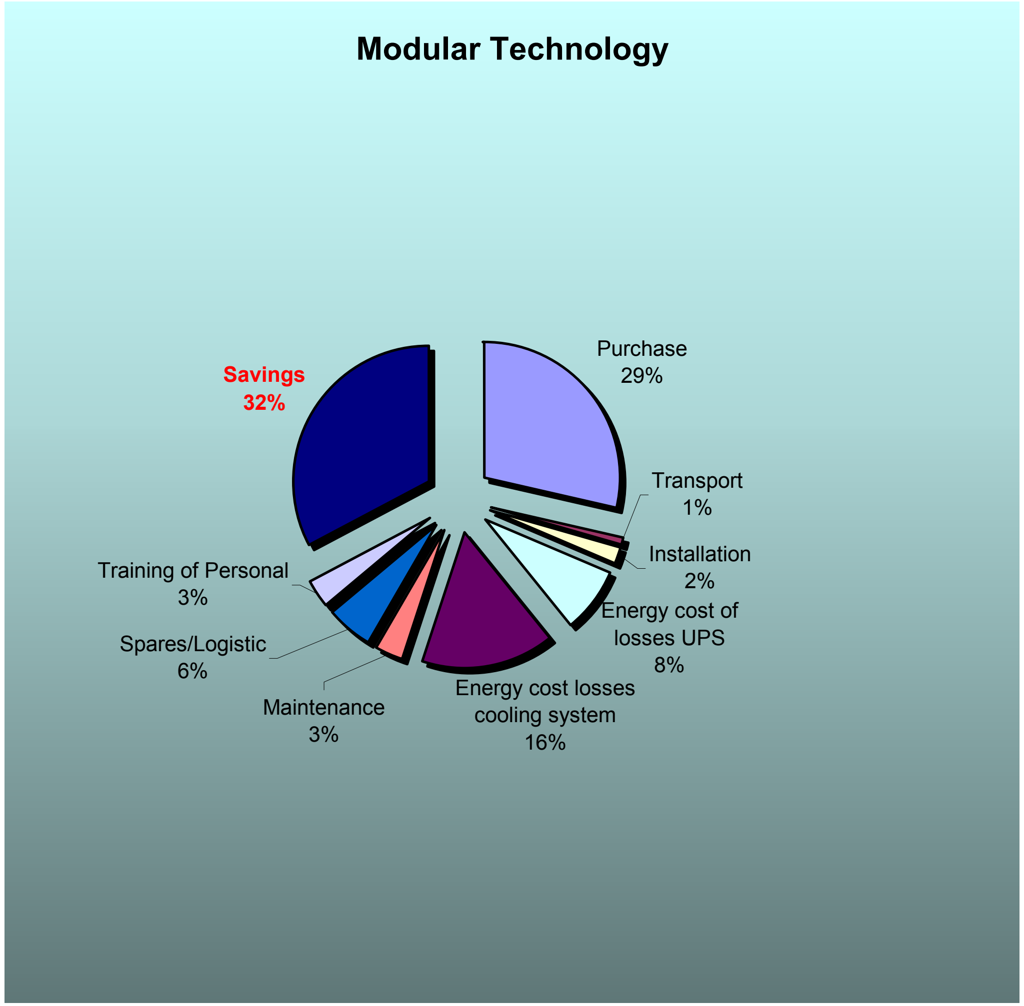
Traditional Configuration: 2 x 80 kVA for a total load of 80 kVA (**Load 50%** per system unit)
Modular Configuration: 3 x 40 kVA for a total load of 80 kVA (**Load 66.7 %** per module)

The following calculation model assumes that the modular configuration is 100% and the UPS with the traditional technology expressed as a percentage (%) compared with the cost of the modular configuration. The table shows general typical values:

Summery of case	**Traditional Technology** 2x80KVA (1+1) Load: 80KVA	**Modular Technology** 3x40kVA (2+1) Load : 80KVA	**Savings** (+) compared with **Traditional technology**
Purchase Costs			
Purchase Price	82 %	100 %	Typically 22 % (-)
Transportation cost	150 %	100 %	Typically 33 %
Building Cost / Floor Cost			
Installation cost	150%	100 %	Typically 33 %
Security Concept (Redundancy, Availability)	143 %	100 %	Typically 30 %
Operating Cost			
Energy losses of USV (technology dependent)	2x4.8KW = **9.6KW** (50% load, η=0.87 typical value)	3x1.6KW = **4.8KW** (67% load, η=0.93 typical value)	**4.8 kW** losses Typically 50 %
Energy cost for losses of a UPS system within 5 years	**2x41'877 Euro** within 5 years at 0.2 Euro/kWh	**3x14'137** Euro within 5 years at 0.2 Euro/kWh	**41'343** EURO within 5 years Typically 50 %
Additional energy cost for losses of the cooling system within 5 years	**2x83'774 Euro** within 5 years at 0.2 Euro/kWh	**3x28'273 Euro** within 5 years at 0.2 Euro/kWh	**82'729** EURO within 5 years Typically 50 %
Total Energy costs of the losses within 5 years	**251'302 Euro** within 5 years at 0.2 Euro/kWh	**127'233 Euro** within 5 years at 0.2 Euro/kWh	**124'072 Euro** within 5 years at 0.2 Euro/kWh Typically 50 %
Maintenance cost	143%	100%	Typically 30%
Spare part stock and logistic	200%	100%	Typically 50%
Training of Maintenance personal	Up to 300%	100%	Typically up to 67%
Upgrade Cost			
Upgrade costs (Flexibility, Upgrade without any interruption of load)	100% (with interruption)	None **(without interruption)**	Typically 100%
Total savings within the 1st year of operation			
Total Savings	0%	-32 %	**Typically 32 %**

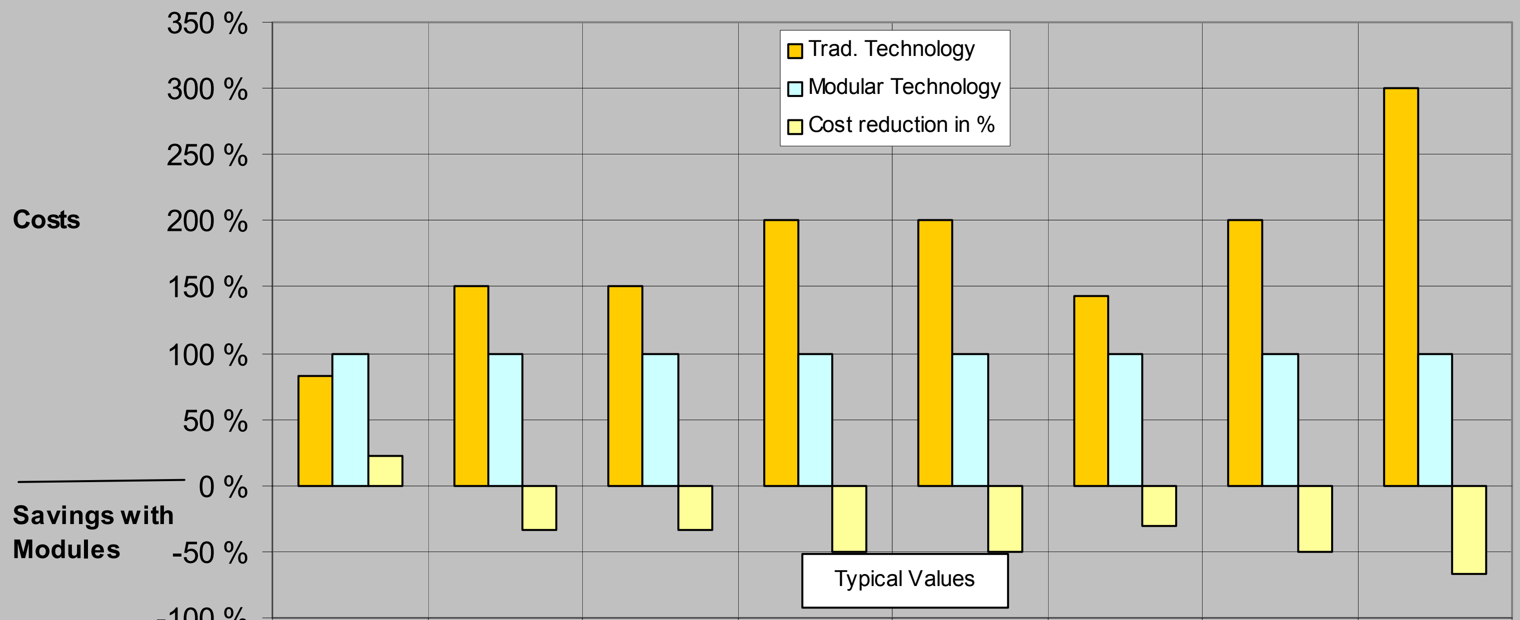
Cost comparison within the 1st year of operation





Cost comparison of individual cost segments on a percentage basis:

Example : 2x80kVA //-redundant
Cost comparion - Traditional/Modular UPS-Technology witin the 1st year of operation



	Purchase	Transport	Installation	Energy costs loses UPS	Energy costs loses cooling system	Maintenance	Spares/Logistic	Training Personal
Trad. Technology	82 %	150 %	150 %	200 %	200 %	143 %	200 %	300 %
Modular Technology	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Cost reduction in %	22 %	-33 %	-33 %	-50 %	-50 %	-30 %	-50 %	-67 %

Cost segments

[1)] **Attachment: Calculations of energy losses of a traditional UPS system**

COMPARISON: UPS RUNNING COSTS WITH DIFFERENT EFFICIENCIES on PARTIAL LOAD

80 kVA	Blue field are variables	UPS and Cooling System / transformer based UPS's												
		Efficiency (%)												
Rated Load 80.00 kVA	cosphi = 0.80	0.87	0.88	0.89	0.9	0.91	0.92	0.93	0.94	0.95	0.955	0.96	0.965	0.97
						Typical Value for transformer based UPS at 100% load								
100 % of UPS rated load	64 kW													
Losses with 100% load (in kW)		9.6	8.7	7.9	7.1	6.3	5.6	4.8	4.1	3.4	3.0	2.7	2.3	2.0
Total losses in one year (kWh)	x 8'760.00 h	83'774	76'451	69'293	62'293	55'448	48'751	42'199	35'786	29'507	26'418	23'360	20'334	17'339
UPS-running costs in 1 year (EURO)	x 0.20 EURO/kWh	16'755	15'290	13'859	12'459	11'090	9'750	8'440	7'157	5'901	5'284	4'672	4'067	3'468
UPS-running cost in 5.00 years (EURO)	x 5.00	83'774	76'451	69'293	62'293	55'448	48'751	42'199	35'786	29'507	26'418	23'360	20'334	17'339
Cooling-Heat Evacuation Losses (EURO)	min. x 2.00	167'548	152'902	138'585	124'587	110'896	97'503	84'397	71'571	59'015	52'835	46'720	40'668	34'679
Total Running cost in 5.00 years (EURO)		**251'321**	**229'353**	**207'878**	**186'880**	**166'344**	**146'254**	**126'596**	**107'357**	**88'522**	**79'253**	**70'080**	**61'002**	**52'018**
	Typical Value for transformer based UPS at 50% load													
		Efficiency (%)												
Partial laod	cosphi = 0.80	0.87	0.88	0.89	0.9	0.91	0.92	0.93	0.94	0.95	0.955	0.96	0.965	0.97
50 % of UPS rated load	32 kW													
Losses with 100% load (in kW)		4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.7	1.5	1.3	1.2	1.0
Total losses in one year (kWh)	x 8'760.00 h	41'887	38'225	34'646	31'147	27'724	24'376	21'099	17'893	14'754	13'209	11'680	10'167	8'670
UPS-running costs in 1 year (EURO)	x 0.20 EURO/kWh	8'377	7'645	6'929	6'229	5'545	4'875	4'220	3'579	2'951	2'642	2'336	2'033	1'734
UPS-running cost in 5.00 years (EURO)	x 5.00	41'887	38'225	34'646	31'147	27'724	24'376	21'099	17'893	14'754	13'209	11'680	10'167	8'670
Cooling-Heat Evacuation Losses (EURO)	min. x 2.00	83'774	76'451	69'293	62'293	55'448	48'751	42'199	35'786	29'507	26'418	23'360	20'334	17'339
Total Running cost in 5.00 years (EURO)		**125'661**	**114'676**	**103'939**	**93'440**	**83'172**	**73'127**	**63'298**	**53'678**	**44'261**	**39'626**	**35'040**	**30'501**	**26'009**

[1)] Attachment: calculation of energy losses of a Modular UPS system

COMPARISON: UPS RUNNING COSTS WITH DIFFERENT EFFICIENCIES on PARTIAL LOAD

40 kVA	Blue field are variables	UPS and Cooling System / transformerless based UPS's												
		Efficiency (%)												
Rated Load 40.00 kVA	cosphi = 0.80	**0.87**	**0.88**	**0.89**	**0.9**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.955**	**0.96**	**0.965**	**0.97**
100 % of UPS rated load	32 kW													
Losses with 100% load (in kW)		4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.7	1.5	1.3	1.2	1.0
Total losses in one year (kWh)	x 8'760.00 h	41'887	38'225	34'646	31'147	27'724	24'376	21'099	17'893	14'754	13'209	11'680	10'167	8'670
UPS-running costs in 1 year (EURO)	x 0.20 EURO/kWh	8'377	7'645	6'929	6'229	5'545	4'875	4'220	3'579	2'951	2'642	2'336	2'033	1'734
UPS-running cost in 5.00 years (EURO)	x 5.00	41'887	38'225	34'646	31'147	27'724	24'376	21'099	17'893	14'754	13'209	11'680	10'167	8'670
Cooling-Heat Evacuation Losses (EURO)	min. x 2.00	83'774	76'451	69'293	62'293	55'448	48'751	42'199	35'786	29'507	26'418	23'360	20'334	17'339
Total Running cost in 5.00 years (EURO)		**125'661**	**114'676**	**103'939**	**93'440**	**83'172**	**73'127**	**63'298**	**53'678**	**44'261**	**39'626**	**35'040**	**30'501**	**26'009**
		Efficiency (%)												
Partial laod	cosphi = 0.80	**0.87**	**0.88**	**0.89**	**0.9**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.955**	**0.96**	**0.965**	**0.97**
67 % of UPS rated load	21 kW													
Losses with 100% load (in kW)		3.2	2.9	2.6	2.4	2.1	1.9	1.6	1.4	1.1	1.0	0.9	0.8	0.7
Total losses in one year (kWh)	x 8'760.00 h	28'064	25'611	23'213	20'868	18'575	16'332	14'137	11'988	9'885	8'850	7'826	6'812	5'809
UPS-running costs in 1 year (EURO)	x 0.20 EURO/kWh	5'613	5'122	4'643	4'174	3'715	3'266	2'827	2'398	1'977	1'770	1'565	1'362	1'162
UPS-running cost in 5.00 years (EURO)	x 5.00	28'064	25'611	23'213	20'868	18'575	16'332	14'137	11'988	9'885	8'850	7'826	6'812	5'809
Cooling-Heat Evacuation Losses (EURO)	min. x 2.00	56'128	51'222	46'426	41'737	37'150	32'663	28'273	23'976	19'770	17'700	15'651	13'624	11'617
Total Running cost in 5.00 years (EURO)		**84'193**	**76'833**	**69'639**	**62'605**	**55'725**	**48'995**	**42'410**	**35'964**	**29'655**	**26'550**	**23'477**	**20'436**	**17'426**

Typical Value for transformerless UPS at 100 % load (→ 0.95)

Typical Value for transformerless UPS at 50 % load (→ 0.93)