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The System Cost Model: A Tool for Life Cycle Cost and Risk Analysis

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ABSTRACT

In May of 1994, Lockheed Idaho Technologies Company (LITCO) in Idaho Falls, Idaho and subcontractors began development of the System Cost Model (SCM) application. The SCM estimates life cycle costs of the entire U.S. Department of Energy (DOE) complex for designing; constructing; operating; and decommissioning treatment, storage, and disposal (TSD) facilities for mixed low-level, low-level, and transuranic waste. The SCM uses parametric cost functions to estimate life cycle costs for various treatment, storage, and disposal modules which reflect planned and existing waste management facilities at DOE installations. In addition, SCM can model new TSD facilities based on capacity needs over the program life cycle. The user can provide input data (default data is included in the SCM) including the volume and nature of waste to be managed, the time period over which the waste is to be managed, and the configuration of the waste management complex (i.e., where each installation's generated waste will be treated, stored, and disposed). Then the SCM uses parametric cost equations to estimate the costs of pre-operations (designing), construction, operations and maintenance, and decommissioning these waste management facilities. The SCM also provides transportation costs for DOE wastes. Transportation costs are provided for truck and rail and include transport of contact-handled, remote-handled, and alpha (transuranic) wastes.

A complement to the SCM is the System Cost Model - Risk (SCM-R) model, which provides relative Environmental, Safety, and Health (ES&H) risk information. A relative ES&H risk basis has been developed and applied by LITCO at the INEL. The risk basis is now being automated in the SCM-R to facilitate rapid risk analysis of system alternatives. The added risk functionality will allow combined cost and risk evaluation of EM alternatives.

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1. INTRODUCTION

The System Cost Model (SCM) was designed based on the cost knowledge developed for the Waste Management Programmatic Environmental Impact Statement (WM PEIS). The WM PEIS demanded that a consistent life cycle cost system be developed and utilized for cost analysis and data input for risk assessments and socioeconomic analysis. The WM PEIS analyses were successfully performed on various waste management alternatives for low-level waste (LLW), mixed low-level waste (MLLW), and transuranic waste (TRU). The engineering basis for the SCM was derived from WM PEIS technical reports: *Waste Management Facilities Cost Information for Low-Level Waste*[1], *Waste Management Facilities Cost Information for Mixed Low-Level Waste*[2], *Waste Management Facilities Cost Information for Transuranic Waste*[3], and *Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Material*[4]. This cost information as programmed in the SCM provides DOE with a tool to perform waste management sensitivity analysis on the Baseline Environmental Management Report and Technology Development applications.

Sponsors

Lockheed Idaho Technologies Company's (LITCO's) Technical Support Program with contractor assistance from MK-Environmental Services (MKES) developed the System Cost Model (SCM) at the request of the Department of Energy's (DOE's) Office of Waste Management (EM-30). Further development and refinement of the SCM for technology development applications is sponsored by the DOE Office of Science and Technology.

What Is the SCM?

The SCM estimates life cycle costs of the entire U.S. Department of Energy (DOE) complex for designing; constructing; operating; and decommissioning treatment, storage, and disposal (TSD) facilities for LLW, MLLW, and TRU (including mixed TRU). The SCM uses parametric cost functions to estimate these life cycle costs. Parametric cost functions develop costs for various treatment, storage, and disposal modules which reflect planned and existing facilities at installations. In addition, SCM can model new facilities based on capacity needs over the program life cycle. The user can provide input data (default data is included in the SCM) including the volume and nature of waste to be managed, the time period over which the waste is to be managed, and the configuration of the waste management complex (i.e., where each installation's generated waste will be treated, stored, disposed, and transported). Then the SCM uses parametric cost equations to estimate the costs of the following program life cycle phases of waste management facilities.

Pre-operations—Pre-operations pertain to the studies and bench scale test costs, demonstration costs, and operations budget funded activities (conceptual design, safety assurance documentation, permitting, preparation for operation, and project management).

Construction costs—Construction costs include title I and II design, inspection, project management, building construction (including indirect costs), equipment (including indirect costs), construction management, and contingency costs related to facility construction.

Operation and Maintenance—Operations and Maintenance relates to operating labor, utilities, material, maintenance, and other costs including reserve and contingency costs.

Decommissioning—Decommissioning pertains to manpower, surveillance and maintenance, assessment and characterization, environmental documentation review, operations, closure, and post-closure monitoring.

Examples of Current Uses for the SCM

Baseline Environmental Management Report. The SCM has been used in FY-95 and FY-96 to support the preparation of the Waste Management Portion of the Baseline Environmental Management Report (BEMR). In order to support BEMR modeling efforts, the SCM has been calibrated for each of the six major DOE sites. The calibration is done so that SCM can simulate the BEMR cost estimates for these sites and represent their existing and planned waste management facilities in the complex-wide BEMR modeling activities. DOE then uses the BEMR treatment option within the SCM to conduct sensitivity analysis.

To increase the accuracy of the model for BEMR analysis activities, the SCM was calibrated to the baseline plans at the six major DOE installations (i.e., Hanford Site, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge Reservation, Rocky Flats Environmental Technology Site, and the Savannah River Site). These six sites represent over 80% of the waste management costs within the DOE complex. The calibration effort included site visits and intense data gathering to:

- Customize SCM with site-specific input data;
- Calibrate modeled estimated operation and maintenance costs to the sites cost for existing treatment, storage, and disposal facilities;
- Calibrate algorithms for studies and bench scale test, demonstration, construction, and operations to the site's assumptions for facility design, construction, and operations costs; and
- Develop cost relationships to derive a total site waste management cost (including program management and other site overheads) from modeled SCM facility costs.

Technology Development. The SCM will be used in FY-96 to perform technology assessments on thermal and non-thermal treatment systems. The SCM will aid Technology Development in estimating system and sub-system cost variations due to: changes in waste streams loading, schedules (e.g., long-term storage, varying operation periods), pre-treatment requirements (e.g., sorting, characterization, handling), waste form variations on disposal requirements, and transportation (e.g., containers, packaging).

Examples of the type of analysis that can be performed using the SCM for Technology Development include:

- Evaluation and comparison of new thermal treatment technologies and non-thermal (washing) technologies;
- Comparison of effects from final waste form (e.g., grout, glass) on transportation and disposal costs and risks;
- Trade-offs between waste storage costs and risks versus improved technology performance;
- Advantages of combined processing of similar wastes (e.g., alpha LLW, alpha MLLW, mixed TRU waste);
- Optimize performance of treatment systems (e.g., reducing treatment effluents, reducing sorting and characterization).

2. System Cost Model Functionality

The SCM system architecture enables new features to be easily added as the product matures. A high-level, functional view of SCM architecture is shown in Figure 1.

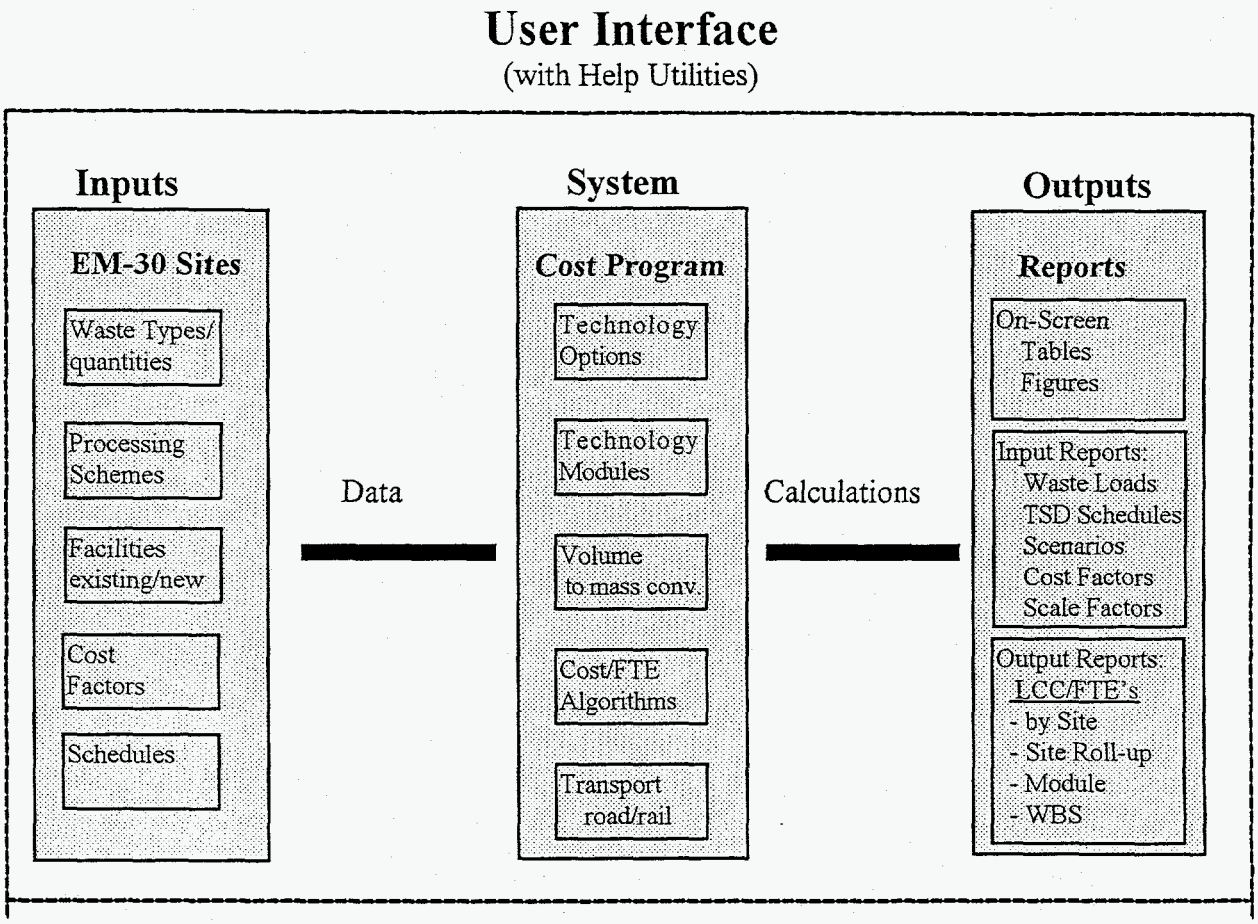

Figure 1. System Cost Model Architecture.

The SCM architecture illustrates the partitioning of the model structure into three distinct components: Inputs, System, and Outputs. The Inputs define the model parameters that are required to execute calculations of the system. The System components consist of the calculation engines required to produce the desired outputs. The Output component provides the desired screens and reports that contain the results from the system calculations and provide a record of the input parameters. Each of these components are described in more detail in the following sections.

3. Input Information

Data from the five required categories (waste loads, TSD scenarios, site schedules, and facility profiles) must be completed for the program to function. It is up to the user's discretion whether to make any changes to the five optional categories (work breakdown structure (WBS) scale factors, other site costs, cost factors, charge backs, and inflation factors). Default data for these five optional categories has been pre-loaded into the SCM.

Waste Load Information

Matrix categories, also termed waste stream fields, are categories of waste that are distinguishable by their origin, physical state or form, composition, radioactivity, or a combination of these characteristics. The waste loads in the SCM are identified by 32 unique matrix categories which are consistent with the classification scheme used in the Mixed Waste Inventory Report. The categorization of wastes also allows summation of common wastes across waste types (i.e., LLW, MLLW, TRU).

Waste loads provide the foundation for the SCM. Facility costs are calculated from algorithms relating cost to capacity, and capacity is derived from waste loads. Waste loads are required for a given waste type (low-level waste, mixed low-level waste, transuranic waste) in order to create a specific case. If waste loads are not defined for any of the waste types, calculations cannot be executed. Waste loads that are in inventory are termed legacy waste. Generated annual waste contributes to the overall waste loads for the SCM case scenario.

Treatment, Storage, and Disposal Scenarios

The user defines the destination of waste for treatment, storage, and disposal (TSD) locations by site (onsite, offsite). The waste can be "split" by the 32 waste matrix categories to go to different DOE sites for treatment, storage, or disposal. For onsite treatment, SCM offers optional treatment schemes that make use of different technologies aimed at meeting various treatment objectives.

Site Schedules

Once the quantity of waste and the treatment, storage, and disposal scenarios have been entered, the SCM allows the user to edit the scheduling of new treatment, storage, and disposal facilities at a site. Site schedules can be manipulated for start and stop dates, and durations of major cost elements (e.g., preoperation, construction, O&M, D&D). Shipping schedules are used to establish when waste moves from storage to treatment. The scheduling information controls storage requirements and will affect the amount and scheduling of costs.

Facility Profiles

The SCM's database contains information about the known DOE site waste management facilities, based on the information available at the time of the release of the SCM application. This information includes capacities, operating periods, and any known upgrade costs or O&M costs. The SCM also contains information for the modules represented by the facilities and the waste type dedications (what kind of waste the module can process).

Optional User Input Data

In addition, the user is allowed to select, enter, or change the following data:

- Offsite DOE treatment unit costs
- Treatment options for each waste type (e.g., Base Case, BEMR Calibrated, Nonflame,)
- Transportation (rail/road)
- Commercial unit costs
- Existing or planned DOE facility cost information
- Site-specific cost factors and labor rates
- Cost escalation factors

User Input Options

The model provides a default set of parameters that SCM users may use to select the site, facility, waste type, etc. The system was designed so that very little input data is required from the user. The SCM contains and provides the following internal reference data:

- Cost data based on Waste Management Facility Cost Information reports;
- Generic schedule data;
- Existing and planned/approved facility capacity and operating parameters (based on latest BEMR);
- Minimum and maximum scaling factors for parametric cost/capacity equations;
- Transportation miles and costs/mile;
- Standard operating parameters (such as years of operations and maintenance);
- Module flow factors (site-specific processing schemes).

Case Changes Can Be Saved

If the user selects to change the data input elements as defined above, the modified data can be saved in scenarios called cases. An SCM user can access the saved cases in the future and perform additional modifications. The SCM cases can be copied to or from different personal computers (PCs) via floppy diskettes or a network media. The user can select different cases and merge these cases into a single case.

4. System Capabilities

The SCM provides the general capability to calculate the total life cycle costs by module for the LLW (alpha, non-alpha, and remote handled), MLLW (alpha, non-alpha, and remote-handled), and TRU waste / MTRU waste (contact and remote handled). The SCM user can chose between different treatment options for each waste type. The following tables provide the treatment options that SCM supports for the 3 major waste types.

Low-level waste (Alpha, Non-alpha, Remote-Handled)

BASE CASE Minimum Treatment	Least level of treatment (solidification)
BASE CASE Regional Treatment	Volume Reduction (incineration and shred/grout)
BEMR Calibrated	Site-specific process flows of 6 large sites
Vitrification	BASE CASE plus liquids and residues are vitrified.

Mixed Low-level waste (Alpha, Non-alpha, Remote-Handled)

BASE CASE	Treats to RCRA standards using incineration for destruction of organics. The debris and residue waste are grouted.
Non-Flame Treatment	Treats to RCRA standards using washing, thermal desorption and aqueous phase oxidation for the removal and destruction of organics. The debris and residue waste are grouted.
BEMR Calibrated	Site-specific MLLW process flow schemes are calibrated for the 6 large sites (should resemble site treatment plans).
Vitrification	BASE CASE treatment option except that the debris and residue waste are vitrified.

Transuranic waste (Contact-Handled, Remote-Handled)

TRU Waste Isolation Pilot Plant - Waste Acceptance Criteria (WIPP WAC)	TRU wastes are examined for compliance with WIPP certification requirements. Wastes not meeting requirements are processed until they meet the WIPP-WAC requirements.
Resource Conservation and Recovery Act (RCRA)	Compliance with RCRA treatment requirements, compliance with the WIPP WAC, and compliance with reduced gas WIPP WAC treatment options.
BEMR Calibrated	Site-specific MLLW process flow schemes are calibrated for the 6 large sites (should resemble the site treatment plans). Small sites default to the WIPP WAC.
Reduced Gas Generation	WIPP WAC with addition of the shredding and compaction for waste stream 5000.

System Calculations

The System calculations include the following:

- Full-time equivalent (FTE) manpower estimates for each module by WBS
- Cost and FTE annual and cumulative profiles for the three selected waste types
- The administrative and support modules are automatically sized and costed
- Cost by general module/facility type (pre-treatment storage, treatment, storage, and disposal)
- Cost by new facilities versus existing facilities
- Portable treatment or commercial treatment options
- Fixed minimum cost of facility modules for waste loads less than the defined module capacity range
- Summation of DOE complex cost roll-ups of all DOE sites
- Integrated transportation costs (combination of road and rail)
- Calculations to allow facility capacity versus operating period manipulations

Unique System Features:

The System also has unique capabilities which allow waste shedding, which allows a site to distribute the same waste stream to several sites including a commercial designation. Disposal shedding also allows the generating site to distribute waste treated at one treatment location to multiple disposal sites. A user can also designate offsite processing for treatment and/or disposal of waste. In past versions, the SCM automatically built a new facility that would be decontaminated and decommissioned. To more accurately provide full life cycle costs, a finite lifetime constraint is placed on all new facilities (default of 30 years which can be configured by the user up to 50 years). The SCM automatically calculates pre-treatment storage based on user decisions of the earliest construction start date of new facilities and waste scheduling. The system also automatically calculates post-treatment storage based on availability of disposal facilities. Waste storage or disposal costs can also be charged back to the generating sites. This charge is based on the quantity of waste and either a calculated unit rate or a user-provided unit rate.

The total life cycle costs for each module are organized based on the work breakdown structure (WBS) outlined in Table 1.

Table 1. SCM summary level work breakdown structure.

1.0 Pre-operations	5.0 Contracted Services (Commercial)
2.0 Facility Construction Costs	6.0 Offsite Treatment, Storage, or Disposal (DOE)
3.0 Operations and Maintenance	7.0 Transportation
4.0 Decontamination and Decommissioning (D&D)	8.0 Special Site Costs
	9.0 TSD Support Admin. Costs

5. Output Capabilities

The SCM provides the following reporting capabilities:

- Prints user-selected case summary or site detail reports; case summary, site detail, or case comparison graphs; and case Gantt charts.
- Preview option for viewing reports on the screen before printing reports.
- Data exports into text database, spreadsheet, and word processing format.
- Present data in tabular and graphical formats (Figure 2).

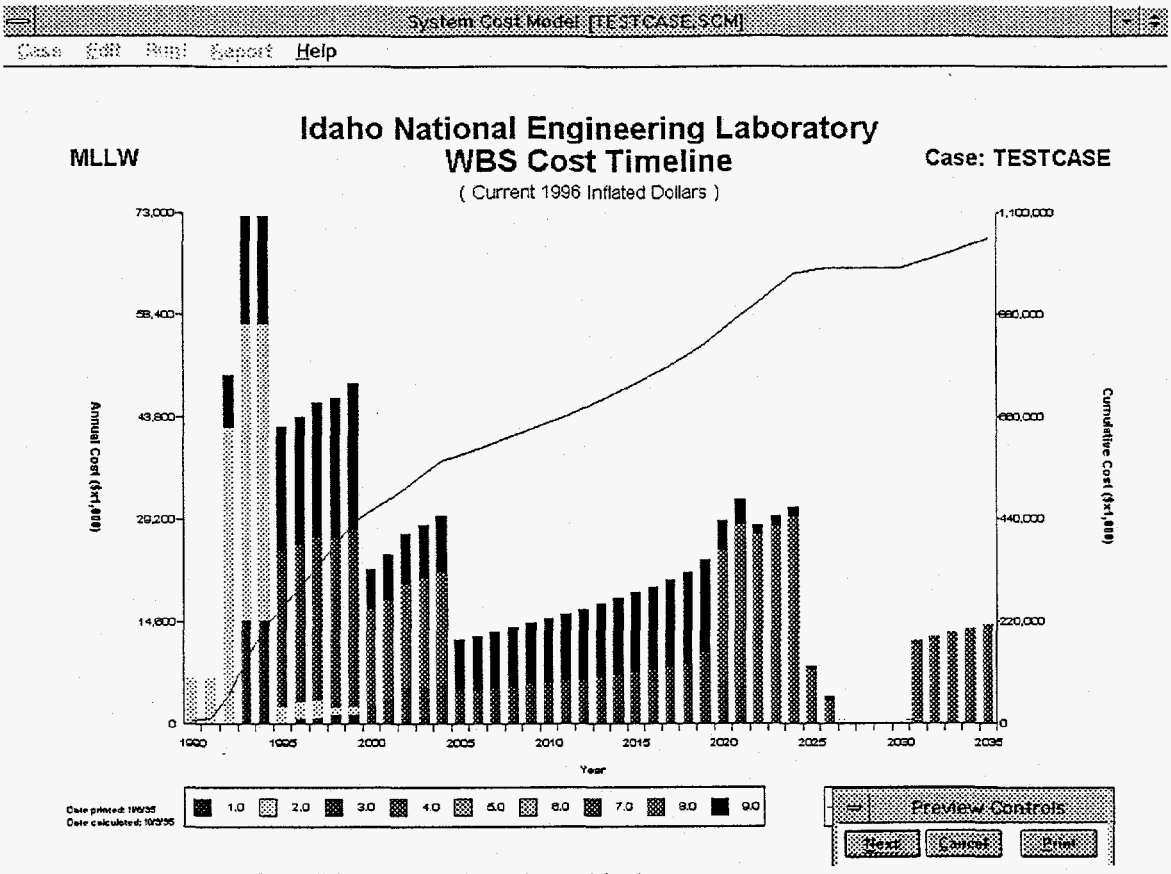

Figure 2. Example of the SCM user-selected graphical report.

6. Relative Risk Analysis Capabilities

The System Cost Model - Risk (SCM-R), a prototype version of the SCM, will provide relative Environmental, Safety, and Health (ES&H) risk information. A relative ES&H risk basis has been developed and applied by LITCO at the INEL. The risk basis is now being automated in the SCM-R to facilitate rapid risk analysis of system alternatives. The added risk functionality will allow combined cost and risk evaluation of EM alternatives. The simplified methodology for ES&H relative risk is composed of the following five elements[5]:

Element 1 - is the characteristics of the waste type which is composed of quantity of contaminants in the waste type and the specific radio toxicity of the radionuclides and/or the specific chemical toxicity of the hazardous chemicals.

Element 2 - expresses the ease with which the contaminants in the waste type could escape confinement as a result of events or conditions that breach the confinement.

Element 3 - expresses the likelihood, or probability, of loss of waste confinement.

Element 4 - how effectively the released contaminants could be moved by environmental transport processes (e.g., wind, groundwater transport, biotic transport) to receptors.

Element 5 - the presence of human receptors. How frequently workers would be located around the waste type, how many workers would be involved, and how closely they would be involved? How many members of the public are located near the waste type, and how close?

The data inputs for the SCM-R includes several parameters from the cost and FTE calculations. These include technology descriptions, waste forms, schedules, transition and rest states, facility capacities, and DOE site-specific information. Additional risk parameters are included in the SCM-R to define the waste characteristics (i.e., radiological and hazardous profiles), mobility, confinement, stresses, transport, worker and public proximity, and time in states. The relative risk will be output from the SCM-R on a comparative state basis, and on an annualized risk basis.

7. Deliverable Software and Documentation

Software distribution of the System Cost Model is under the control of LITCO and the DOE. System modifications and configuration control are closely maintained by the project. New releases of the SCM consist of the following:

1. *SCM Software:* The software consists of an executable version of FoxPro which runs stand-alone on an IBM PC (or compatible) under the Microsoft Windows 3.1 environment.

2. *Product Description*: The SCM Product Description[6] provides the current system description of the model capabilities. The Product Description will be maintained throughout the SCM development cycle to ensure that it is current and accurate. All changes to this document will be done in accordance with the change control procedures established by the WMFCI project manager and LITCO document control.

3. *User's Manual*: A user's manual will be developed to accompany major releases of the SCM. The manual will provide a basic overview of the software and user instructions. In addition to the user manual, user training and a training presentation may be required.

8. Conclusions

This paper has provided a description and overview of the capabilities of the System Cost Model and the System Cost Model - Risk. The SCM calculates life cycle waste management costs based on waste loads. The SCM is loaded with default information that represents the latest available site-specific data collected in support of the 1996 BEMR. The SCM has been successfully applied to several EM-30 programs. The tool will be refined in the future by addition of the relative risk function (SCM-R), and capabilities to provide technology development analysis.

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