Executive Summary of the Deliverable Report M4

Deliverable number: 4.3 SIAT – End User Tool

Deliverable title: D 4.3.1 SIAT – End user tool, containing functionality to define policies; analyse their impacts and sustainability risks by means of model calculations and compare effects of different options.

D 4.3.2 Knowledge integration: Implementation of response functions and fact sheets into the Sustainability Impact Assessment Tools SIAT (Prototype updates months 44, 54).

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Dissemination level

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<td>Restricted to other programme participants (including the Commission Services)</td>
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Executive Summary

This summary gives a brief overview on the joint deliverable 4.3 SIAT – End User Tool. The Sustainability Impact Assessment Tools (SIAT) has been developed throughout the project period of SENSOR and can be considered as central software product of SENSOR (Helming et al. 2008). The SENSOR deliverable 4.3 is split up into the 4.3.1 End user tool, containing functionality to define policies 4.3.2 Knowledge integration into SIAT. This summary provides a brief overview on the applied procedures and components for SIAT development, while each deliverable contains extensive contents and details.

1 Objective

The meta-model SIAT supports integrated ex-ante impact assessments in the scope of multifunctional land use and sustainable development (Helming et al., 2008). SIAT is designed to simulate land use policies to the year 2025 at regional scale of 570 NUTS2/3 regions. Its 83 implemented indicators implicitly synthesise the agriculture sector and herefrom related sectors of forestry, tourism, nature conservation, energy and transport (Sieber et al., 2008, Verweij et al., 2006). The purpose of SIAT targets regionalised trade-off analysis between the sustainability indicators, the valuation by critical limits to build sustainability decision choice spaces and applied indicator aggregations towards the concept of Land Use Functions (LUF) to indicate the provision of 'good and services' at regional level (Perez-Soba et al., 2008).

2 Procedures and methods

To develop SIAT, a general procedure was followed that consisted of a number of applied methods and measures. SIAT has developed on the basis of a non-standardised Model Requirement Analysis that was embedded in a procedure of development phases, which we applied to evolve the SIAT model design. The major single stages of the applied methods and procedures are outlined in the following experience-based guidelines.

Evolutionary prototyping

Three prototypes posed the major mean to structure the group discussions. The hands-on prototype contained a Graphical User Interface with an exemplary implemented model simulation. As predominant objective the prototype should pose a professional 'look and feel' on a range of model functionalities.

The group of developers was composed of natural scientists with different background from software engineers, landscape planners to agricultural economists. Subcontracted graphical artists delivered on-demand design elements. The result was a SIAT prototype composed of (a) a user interface, (b) a topic-structure for content management of fact sheets (c) a simplistic model application for one policy simulation and (d) a visualization mapping component. Reliability on simulation results was not relevant, but continuous feedbacks on design and functionalities served as input for the second and third prototype (see fig. 1)
Prototype-based group discussions with end users

Mixed groups consisted of software engineers, natural scientists and policy experts as potential end users. In practice, the major clients Research Directorate General, members of Directorate Generals as well as of Joint Research Centres IES and IPTS acted as end users. National institutes and various European institutions were involved at the level of scientific conferences and by applying subsidiary informal interviews.

We applied a non-standardized MRA in the form of group discussions on best available experts. Pre-defined compositions of selected types of end users could not be continuously applied due to prevalent institutional dispositions. Based on the given prototype-induced simulation structure and design components, the discussions aimed at surveying end user requirements. Most end user meetings were designed as open discussions focusing on design potentials based on given prototype functionalities and minimum standards to be fulfilled for IA. The SIAT developer group was involved in 79 internal and external interactions. An empiric ex-post evaluation of these interactions was based on available minutes and on applied expert assessments. Based on the accumulated scores, the likelihood for the usefulness for actual successful interactions with regard to the given criteria (a) to (d) could be indicated. This indicator can be interpreted as actual potentiality of the respective user interaction to accomplish MRA (see details of the evaluation scheme in the appendix). By trend evidence appeared that the potentiality to accomplish MRA is rising over the project period due to improved prototype demonstrations.

Institutional analysis by semi-structured interviews

Along with group discussions, subsidiary semi-structured interviews on institutional requirements related to IA and tools for IA were conducted. Interview techniques posed a valuable method to avoid strategic behaviour of potential end users. Within the SENSOR consortium, a different group of scientists was responsible for this research field. Continuing interactions between model developers and scientist assigned to conduct institutional analysis safeguarded necessary information flows (see SENSOR deliverables D7.2.1, D7.4.1, D7.4.2.).

Final negotiations on capacities

The divergence between given capacities and surveyed user-claims needed adjustments on actual design implementation. This last step included the negotiation with involved
institutions on priority setting of outstanding tasks with regard to component-based cost estimates and realistic achievements in given time frames.

### 3 Result Components

As results of the described procedures and the applied methods to design the SIAT, a number of model components have been developed.

**Analytical SIAT default-concept**

Laid down in the project design, SIAT’s default concept aims at supporting decision making on policies related to multifunctional land use in European regions and to provide scientifically substantiated anticipations of the effects of future policy options on sustainability issues (Helming et al., 2008). Demands from the project-design comprised synthesized considerations of social, economic, and environmental effects to be expressed in ‘functions’ or ‘goods and services’ in the landscape context. Assessment streams of European-wide, indicator-based driving force and impact analysis of land use policy scenarios, region specific problem, risk and threshold assessments were major default; supported by complementary data management systems and institutional analysis approaches. On this basis, SIAT aimed at (a) allowing for European-wide ex-ante integrated IA, (b) covering the economic sectors agriculture, forestry, tourism, nature conservation, transport and energy infrastructure and (c) addressing spatially explicit environmental, societal as well as economic functions (Helming et al. 2008).

**Component-based SIAT framework**

Based on the defined analytical concept in the project-design, fig. 2 illustrates the herefrom elaborated basic framework in which SIAT has been developed. The external model chain framework generates the SIAT input information in the form of pre-calculated response protocols. These ‘policy response functions’ describe responses of exogenous policy instrument changes on (intermediate) endogenous indicator variables, which are throughout implemented as exogenous function terms in ‘indicator response functions’. Thematically clustered indicators in the LUF-component are normalised and then aggregated to Land Use Functions (LUF) as indices of compounded results. All meta-model components have been systematically rendered into compatible components of the software architecture, which allow for setting variables of policy instruments. Latter policy instruments can be selected and adjusted on the Graphical User Interface (GUI) to user needs. Based on these policy settings, scenario-based simulations are conducted. Iteratively solved simulation results can be memorised in cache storages to be displayed and compared among each other by means of user-opted visualisation components.
The quantitative results used in SIAT are produced by a system of interlinked models, the model chain framework. It aims at including multiple sectors under the condition of maintaining sector-specific details. The integrated modeling system should address the broad sustainability issues in IIA in a scientifically sound and consistent manner. For this, each sector of importance for sustainable land use was modeled in detail. The agricultural sector is modeled by the agricultural economic model CAPRI which runs at regional level within EU27 (Britz et al., 2008). CAPRI simulates the impact of changing agricultural policies on agricultural production and prices, on subsidies, on input use including fertilizer application and also for several important environmental indicators such as nutrient surpluses and greenhouse gas emissions from agriculture. Forest management practices are computed by EFISCEN (Sallnäs, 1990; Schelhaas et al., 2007). Based on the input data as wood demand and forest area, the state of the forest is described in matrices for each forest type, in which area is distributed over age and volume classes. SICK, TIM and B&B are models for urban growth, transport infrastructure and tourism.

The interdependencies between sectors are handled by linking the sector models to an economy-wide economic model (NEMESIS, see Zagamé et al., 2002; Brécard et al., 2006) and a land use model (Dyna-CLUE, see Verburg et al., 2006; Verburg and Overmars, subm). NEMESIS handles competition for shared factors of production, including land, between the individual sectors, and is also able to simulate the relationship between research and development spending (R&D) and technical progress. NEMESIS also provides results for macro economic indicators including employment and economic growth. Dyna-CLUE disaggregates land claims per sector and member state to square kilometres, and re-aggregates it to regional scales required by CAPRI and EFISCEN. Dyna-CLUE also implements spatially specific policy instruments as Natura 2000 and Less Favoured Area payments. The individual models are linked that results from all sectors are consistent (Jansson et al., 2008). The results have been used to construct policy response functions.
Response function components

Policy response functions

The response functions closely replicate the behaviour of the linked system of models and accomplish to reduce the computation response time down to few seconds. The set of response functions for a policy case is generated by performing and analysing simulation experiments with the models, where the policy instruments are systematically varied to cover the entire domain for that particular policy case, all remaining policy instruments being unchanged.

Let the \((s \times m)\) vector \(Z\) describe the simulation experiment setup for a particular policy case. Each row \(z_i\) of \(Z\) shows the settings of all \(m\) policy instruments in one simulation experiment, and each column shows the setting of a particular policy instrument across all \(s\) simulation experiments. The whole linked system of models is solved once for each row (i.e. \(s\) times), and each solution results in a result \(y_{ij}\) for each of \(j = 1...n\) intermediate variables in each of the \(i = 1...s\) simulation experiments, e.g. land use per region, nutrient surpluses per region, GDP change per region etc. If all such vectors are vertically concatenated we obtain the \((s \times n)\) matrix \(Y\) of intermediate results.

When the simulation setup \(Z\) has been used to generate the matrix of results \(Y\), a quadratic relationship is estimated. An intercept is included by appending a column of “1” to the simulation setup \(Z\), obtaining the explanatory \((s \times (1 + m))\) matrix \(X\). Each row \(i\) of \(X\) thus looks like

\[ x_i = [1 \ z_{i1} \ ... \ z_{ik} \ ... \ z_{im}] \]  where \(k = 1...m\) are policy instruments.

A quadratic relationship between \(x_i\) and \(Y\) is estimated by assuming the model

\[ (*) \quad y_{ij} = x_i'B_jx_i + ij \]  for all \(i = 1...n\) and for all \(j = 1...m+1\),

where \(B_j\) is an \((m + 1) \times (m + 1)\) matrix of coefficients to estimate and \(ij\) is the error associated with the \(i\)th estimation of the \(j\)th variable. The model (*) is quadratic in \(x_i\) but linear in \(B_j\), and can thus be efficiently estimated by ordinary least squares. In fact, it will amount to \(n\) independent estimations. The simulation setup is such that there are two degrees of freedom for each estimation, which is sufficient to compute the share of explained variation \(R^2_j\) for each intermediate variable \(j\). If the quadratic approximation is good and the solution of the linked model system has been successful, an \(R^2\) close to 1 will be obtained. If, however, the \(j\)th variable was reacting in a highly non-linear or discontinuous way to changes in policy instruments, or if there was some numerical problem in the solution process, then the associated \(R^2_j\) will be low. \(R^2\) can be exploited in SIAT to convey to the user a degree of reliability of the results in the respect of how well the response functions approximate the full linked system of models.

For each policy case \(c\), the estimations reported above were repeated, resulting in a separate matrix \(B_{jc}\) for each intermediate variable \(j\). According to users’ selection, the sequence to choose first a policy case \(c\), and then a value for each policy instrument \(j\) is applied. Subsequently, the row vector \(x\) containing a “1” and the value for each policy instrument is constructed. By the simple multiplication \(y_j = x'B_{jc}x\) a value for each intermediate variable can be computed and used in the subsequent calculation in the indicator response function-component.
Indicator response functions

The indicator response function-component assures synthesising different indicator calculation methods and allow for multidisciplinary quick-scan integrated Impact Assessment by means of 83 indicators. Policy response functions pose the linkable component to compute indicators, which are throughout implemented as exogenous function term in ‘indicator response functions’. Latter function type transforms the intermediate policy variables into indicators by means of knowledge rules. The indicator response function-component allows for processing modelling results in different types of indicators, either using model output as indication for gross assumptions (qualitative indicators) or to transform quantitative model outputs in adequate definitions such as units, scales or needed subsidiary meta-information. Driving constraint for selecting the type of indicator was the availability of indicator method and related pan-European data. Each indicator function needs as input exogenous sets of variables on (a) specific indicator-relevant information such as state variables (e.g. soil types) and sets of specific intermediate variables such as land use-change. Latter sets are provided by the policy response functions. The value of each observed variable changes depending on the policy settings. The indicator can be expressed by quantitative, semi-quantitative or qualitative functions. While quantitative results are generated by derived shapes of the assessed mathematical functions, semi-quantitative indicators are expressed by discrete categorical, nominal, and ordinal functions such as class ranges. Pure qualitative indicators simply indicate directions of most likely anticipations.

Graphical User Interface GUI

GUI functionalities

The graphical user interface (GUI) provides the users two pathways: The (a) SIAT application to simulate policy scenarios and access for retrieving (b) background information. The GUI contains a range of functionalities to assure transparency and traceability at user interaction steps along all navigation bars. Link buttons to fact and information summary reports and retrace-links to return to previous steps of logical calculation chains have been implemented.

The SIAT application contains four steps to solve policy scenarios: Step (1) computes the macroeconomic reference scenario values of the impact indicators for the target year. The reference scenario is expressed in ‘business as usual’ assumptions in terms of no-change anticipated trends of the forecasted exogenous land use drivers oil price, expenditures for research and development, labour force, demographic changes and world economic demand. Step (2) provides a navigation menu that allows for selecting types of policy cases. Each policy case contains sets of policy instruments. Within each case the user can select and combine different policy instruments. Either the inclusion of one instrument as such or specifically the degree of the policy intensity can be chosen in the scenario design. Step (3) illustrates the computed scenario results of impact indicators as consequence of the policy settings. Results are presented in interactive visualisation components such as maps, tables and graphs. Photorealistic visualizations support impressions on changes within landscape views. Map layer (Google data) superimpose additional geographical information for specific analysis. Step (4) evaluates policy impact indicators by means of critical limits (thresholds, targets). These sustainability criteria allow for defining sustainability choice spaces, which are based on ex-post scenario comparisons of run simulations. This step aggregates groups of indicators to Land Use Functions (LUF) that indicate the degree on the relative fulfilment of goods and services at regional level. The nine LUFs ‘Provision of work’, ‘Human health and recreation’, ‘Cultural landscape identity’, ‘Residential and non-land based industries and services’, ‘Land based production and Infrastructure’, ‘Provision of abiotic resources’,
‘Support and provision of habitat’ and ‘Maintenance of ecosystem processes’ have been implemented (Perez-Soba et al., 2008).

GUI visualization components

A range of visualization components have been integrated in the GUI design. They comprise interactive geographical maps, spider diagrams, numerical tables and textual summaries (see fig. 7). Emphasis was given to free choice-option for users to select the most adequate type of result illustration. Logic structures to retrieve visualization components in the chain from (a) policy settings to (b) policy impacts towards (c) the valuation of policy effects should support self-explanatory handling.

Fig 3. Components for result visualisations (Sieber et al. 2009)

Beyond the standard-components a number of specific visualisation approaches have been integrated. Additional Google-map layer and 3D-photorealistic visualisation of landscape in 5 km² views support to analyse results by most realistic ‘impressions’ on land use changes.

Fact and information sheets as reference book

240 fact and information sheets have been processed in the manner that they provide all necessary information with regard to the defined assumptions, elaborated methods for impact assessment, background of the project SENSOR as well as related projects. All processes throughout the SENSOR project have been documented. This reference book was developed by involved SENSOR experts and was revised in terms of common language, used terminology, streamlined grammar and general writing style by a team of skilled researcher. All fact and information sheets can be retrieved through implemented navigation bars from the pathways (a) background and (b) application of SIAT.
4 Current State of SIAT End User Tool

Details of model components of the final SIAT version are laid down in the deliverable 4.3.1 and 4.3.2. The SIAT end user tool consists of a three major physical model components. Component 1 comprise all tools related to the software architecture and Graphical User Interface (SENSOR deliverable 4.3.1), component 2 consist of all content-related computation and information tools (SENSOR deliverable 4.3.2) as well as component 3 developed visualisation tools beyond SIAT standard visualisation tools (SENSOR deliverable 4.4.1).

With regard to the current state of the development, all SIAT components are finalised towards their claimed operational functionality as stand-alone component. But the system integration of developed components has not been achieved within project lifetime of SENSOR. In detail, the following components work in most instances separately: (1) SIAT software architecture and LUF component, (2) meta model indicator-computation of 83 indicators compute simulations results, (3) a reference hand book with more than 200 pages on fact and information was implemented as well as a (4) number of separately developed visualisation tools beyond SIAT standard tools (photorealistic 3D visualisations of landscape views, rendered landscaped schematisation of landscape views, Google map dialogue, visualisation matrix) could be generated.

Figure 4: Final SIAT version (see deliverable 4.3.1 and deliverable 4.3.2)

Major reasons for above described drawbacks are the time shifts of needed information inputs. Due to the organisation in module structure, it was more efficient to develop in parallel processes stand alone components. Therefore, the software architecture of SIAT was developed by Alterra. ZALF developed the meta-model component to compute the indicators as well as managed and elaborated all fact and information sheets. Furthermore, a number of additional visualisation tools have been developed (see separate deliverable 4.4) by TUM, Lenne 3D. All components work separately stand-alone, but capacity needs to develop each component have been underestimated. Transactions costs for communication were high and a number of problems had been solved (e.g. information efforts by indicator experts, result
of the modelling framework etc.). Thus, the complete system integration has not been achieved until end of the SENSOR project. The accomplishment of the system integration is envisaged beyond the SENSOR project. Currently, statements on potential self-commitments of involved institutes are being discussed. Furthermore, interest was raise to continue in the SENSOR consortium endeavours to apply for further project funding.
## 5 Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Baseline scenario</td>
<td>A scenario used as a counterfactual for assessing the impact of policy changes. This contains projections of exogenously assumed developments on which investigated policies do not have influences. In SENSOR, the baseline scenario is defined as the 'business as usual' scenario, where the trends of the assumed drivers don't change.</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GUI</td>
<td>Graphical User Interface</td>
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<td>Fact Sheet</td>
<td>Fact sheets summarise specific topics in SIAT. They are implemented to inform the policy maker about the content / background or defined assumptions of all calculation steps, applied methodologies and methods.</td>
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<tr>
<td>IA</td>
<td>Impact Assessment</td>
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<tr>
<td>Indicator functions</td>
<td>Indicator functions are defined as a mathematical functions and / or a knowledge rule that uses 'land use change' and 'policy variables' (e.g., subsidies) as variables and computes in SIAT indicator values for a specific region.</td>
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<tr>
<td>LUC</td>
<td>Land Use Change</td>
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<td>MRA</td>
<td>Model Requirement Analysis</td>
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<td>LUF</td>
<td>Land Use Function</td>
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<tr>
<td>NUTSX</td>
<td>Harmonisation of NUTS2 and NUTS3 regionalisation</td>
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<td>Open-MI</td>
<td>OpenMI provides a standard interface, which allows models to exchange data with each other and other modelling tools on a time step by time step basis as they run <a href="http://www.openmi.org">www.openmi.org</a></td>
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<td>Policy case</td>
<td>Subject for a set of policy instruments to be applied around a particular theme: EU sugar policy, bio-energy policy case (Biomass, Bio-heat, Bio energy etc.). Within a policy case, different policy variables can be combined, which will be used for defining policy scenarios. In the case of SENSOR synonym for &quot;policy scenario&quot; =&gt;impacts of different scenarios will be compared.</td>
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<td>Policy functions</td>
<td>Policy functions are integrated in a response functions that is implemented in SIAT. They compute the relation between the 'policy intensity' (e.g., subsidy) and the land use claim of one specific sector (e.g., agriculture) or intermediate variables (e.g., GDP), if land use claims are not needed as an interim step to calculate indicator values for one region.</td>
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<td>Policy instrument</td>
<td>Delivery mechanisms including individual element/design parameter. In general they can comprise: regulatory watch, open method of co-ordination, provision of information and guidelines, market-based instruments - taxes or charges, limits to price and/or quantity, etc. - direct public sector financial interventions, co-regulation, framework directives. Example for the sugar policy: instrument for market regulation - prices or quota, tariff restriction trade, etc.</td>
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<td>Policy objective</td>
<td>Aim of the policy, understanding of what a policy is supposed to achieve. Two examples from the EU sugar policy IA:</td>
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<td>• To guarantee regular supplies of sugar while protecting the EU market from extreme price fluctuations.</td>
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<td></td>
<td>• To make the sector more competitive and able to stand up to international competition.</td>
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<tr>
<td>Term</td>
<td>Definition</td>
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<td>Policy option</td>
<td>Set of policy instruments, one of several ways to achieve the objective(s) of a policy. Four policy options have been considered for the EU Sugar Policy: Status quo, price fall, fixed quotes, liberalisation, the “no EU option” should always be considered.</td>
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<tr>
<td>Policy scenario</td>
<td>According to EEA Glossary: Policy scenarios (in the context of environmental studies) depict the future consequences of policy interventions. In other words, they describe the future state of society and the environment under influence of directed environmental policies. Policy scenarios are also known as 'pollution control' or 'mitigation' or 'intervention' scenarios.</td>
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<td>Policy target</td>
<td>Specification of a policy objective in quantitative terms, accompanied by a point in time at which the target will have to be achieved. In some cases a qualitative target will be necessary (if not quantifiable).</td>
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<td>Policy variable</td>
<td>A set of policy instruments within a policy case, expressed monetarily or non-monetarily; the variable is the model-based translation of a policy instrument into a mathematical function.</td>
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<td>Reference scenario</td>
<td>Scenario against which the impact of policy options will be compared and assessed: continuation of the current EU policy; other drivers set at continuation of expected trends or most likely trend for the respective target year.</td>
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<td>SIA</td>
<td>Sustainability Impact Assessment</td>
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<td>SIAT</td>
<td>Sustainability Impact Assessment Tools (SIAT)</td>
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<td>SQL</td>
<td>Structured Query Language is a querying language for querying, modifying, and managing databases and their data.</td>
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<td>SRRF</td>
<td>Spatial Regional Reference Framework</td>
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<td>XML</td>
<td>Extensible Markup Language is general-purpose specification for creating custom markup languages: often called meta language.</td>
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</tbody>
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6 References


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SENSOR, 2008, 7.4.1/6.4.1 Recommendations for SIAT design based on stakeholder-inclusive validation (joint with D6.3.1), SENSOR deliverable report.

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