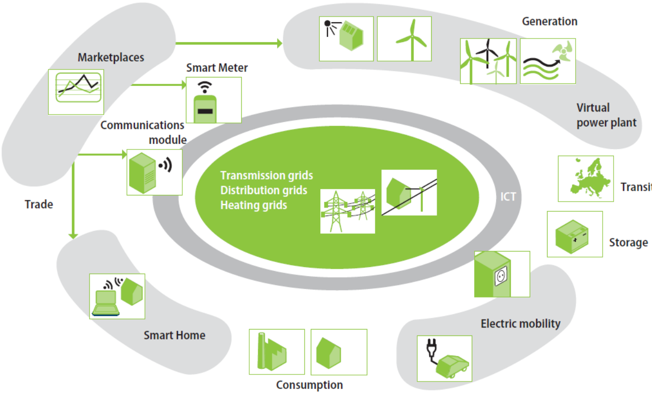
1. Motivation



Quelle: acatech, Future Energy Grid

Energy Management

- Synchronizing supply and demand
- Prognosis of supply and demand
- Load shifting
- Controlling power generating systems, managing storage devices
- Ancillary services for distributed resources: balancing power, reactive power,...
- Energy efficiency, user behavior

All these tasks are based on data.

Need to

- Model data,
- query and update data,
- react on data changes and model what has to happen,
- construct messages to communicate.

2. Data Modelling

Example

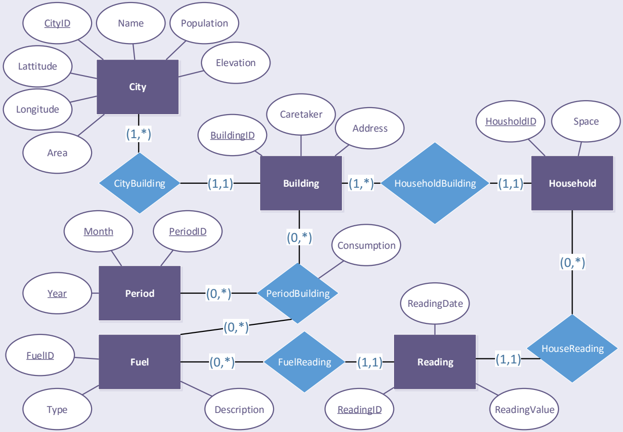
To be able to forecast energy consumption we maintain a database to record the consumption of cities households.

To this end we need data about cities, their buildings, the corresponding households and their energy consumption values taken as readings with respect to periods. To make the data and the relationships between data explicit we develop a model.

The model should show what we need to know about

- cities: *Name, Population, Area, Elevation, Latitude, Longitude,*
- buildings: *Address, Housekeeper*
- households: *Space*
- readings: *Date, Value, Fuel.*

Entity-Relationship Diagram (ER-Diagram, ERD)



Entity-Sets are represented by rectangles, their *properties (attributes)* by ovals, *Relationship-Sets* by diamonds, which are further described by *cardinalities* attached to the connecting lines.

a set of entities represented by a table

Building

BuildingID	Caretaker	Address
100	Miller	A-Street
200	Meier	B-Street
300	Schulze	C-Street
⋮	⋮	⋮

a set of relationships represented by a table

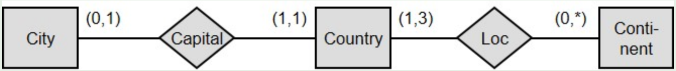
CityBuilding

CityID	BuildingID
C-1234	100
C-1234	200
C-4567	300
⋮	⋮

Keys, Entities, and Relationships

- *Entities* must be uniquely identifiable by a *key*, i.e. a selected number of attributes graphically indicates by underlining. Typically, an artificial attribute like cityID, buildingID, etc. acts as a *surrogate key*
  For example, to identify a building, the name of the city and the address would suffice, as well.
- *Relationships* must be uniquely identifiable by the keys of the involved entities. Relationships can be defined over two or more entities, in general.

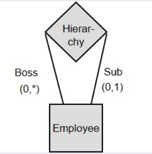
Example

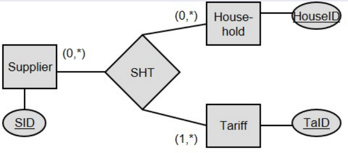


Cardinalities

- Let E —— R be an edge connecting entity-set E and relationship-set R which is labelled by (min, max), $min \leq max$.
- (min, max) is called *cardinality* of E with respect to R.
- A *cardinality* (min, max) of E with respect to R states that each entity $e \in E$ is involved in at least *min* and at most *max* relationships $r \in R$.
- "$*$" used for *max* means arbitrarily many.

Examples.



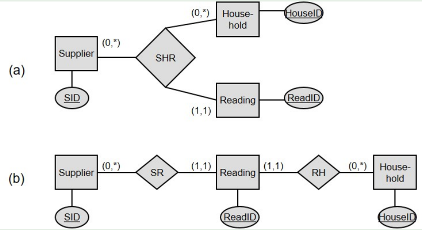


recursive relationships

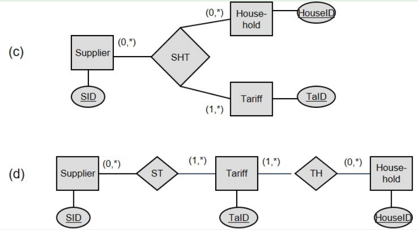
- A relationship-set is *recursive*, if it is connected to the same relationship-set more than once.

  For recursive relationship-sets we have to introduce *roles*.
- A relationship-set may be defined over more than two entity-sets.

Decomposition of relationship-sets.



(a) and (b) describe the same world;



(c) and (d) do not.

Example: why decomposition is not (always) allowed!

SHT

Supplier SID	Household HouseID	Tariff TaID
Energiedienst	1020	Eco
Badenova	1020	Maxi
Badenova	1030	Eco

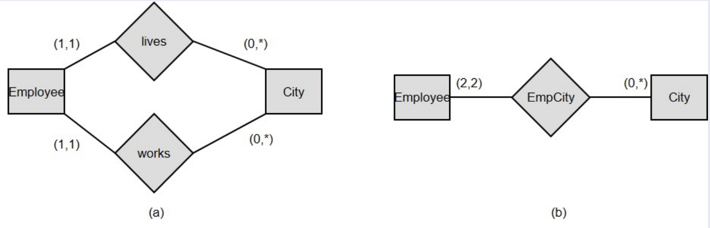
SO

Supplier SID	Tariff TaID
Energiedienst	Eco
Badenova	Maxi
Badenova	Eco

TH

Tariff TaID	Household HouseID
Eco	1020
Maxi	1020
Eco	1030

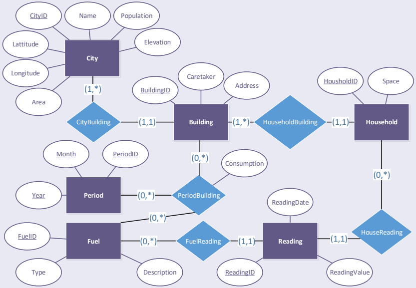
The same entity-sets may be involved in more than one relationship-set.



(a) and (b) describe different worlds - might have two living-addresses and no working address in (b).

3. Data Representation

Example: Mapping ER-Diagrams to Tables (Relations)



Tables for:

- `City`, with columns for `CityID`, `Name`, `Population`, `...`,
- `Building`, with columns for `BuildingID`, `CityID`, `Caretaker`, `Address`,
- etc.

Remark: the relationship-set `CityBuilding` becomes part of table `Building`. This approach does not work for `PeriodBuilding`! But it works for `HouseholdBuilding`, `HouseReading`, `FuelReading` analogously.

Definition of tables representing the information content modelled by the ER-Diagram

```
City(CityID, Name, Population Elevation, Lat, Long, Area)
Building(BuildinID, CityID, Caretaker, Address)
Household(HousID, BuildingID, Area)
Reading(ReadingID, HouseID, Date, Fuel, ReadinValus)
Fuel(FuelID, Type, Description)

Period(PeriodID, Year, Month)
PeriodBuilding(PeriodID, BuildingID, FuelID, Consumption)
```

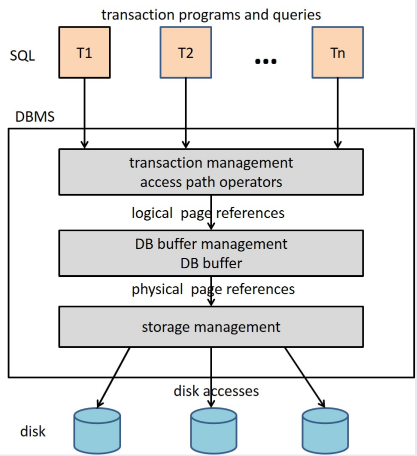
The rows of the tables contain the data - each column for each rows contains one value.

A system, which is able to process a set of tables, each containing a (very) large number of rows, is called *Relational Database System (DBS)*.

- To store, access and process the data managed by a DBS we need a language: SQL
- For scalability, a DBS is composed of layers: the user communicates with the layer called *Data Base Management Software (DBMS)*, which organizes the access to the data efficiently.
- The data typically is stored on disks.

We concentrate on SQL.

Basic Architcture of a DBMS



4. SQL

http://dbissql.informatik.uni-freiburg.de/dbis/energy/sql.php

There you can work with a database of size:

Name of City	Buildings	Households	Readings
Freiburg im Breisgau	10877	97061	2329464
Karlsruhe	14446	128028	3072672
Kehl	1715	14827	355848
Stuttgart	29383	262710	6305040
Σ	56421	502626	12063024

Note: artificial numbers!

How to create a table:

```
CREATE TABLE City {
    CityID          NUMBER,
    Name            VARCHAR(80),
    Population      NUMBER,
    Area            NUMBER,
    Elevation       NUMBER,
    Latitude        NUMBER,
    Longitude       NUMBER,
PRIMARY KEY (CityID) };
```

The primary key (a surrogate) is chosen to guarantee unique identification of every city. Alternative: `PRIMARY KEY (Latitude, Longitude)`.

How to avoid dangling references between tables:

```
CREATE TABLE Building {
    BuildingID       NUMBER,
    CityID           NUMBER,
    Address          VARCHAR(40),
    Caretaker        VARCHAR(40),
PRIMARY KEY (BuildingID),
FOREIGN KEY (CityID) REFERENCES City (CityID) };
```

The references clause guarantees that there will be no tuples in relation `Building`, for which the referenced city does not exist in table `City`.
The *referential integrity* is guaranteed. Later: *referential actions* (e.g., what happens if the city is deleted).

How to pose simple queries to a table:

In each case, the result is also a table!

- Give me all rows of a table.

  ```
  SELECT * FROM City;
  ```

- Give me for all rows only the values of certain columns of a table.

  ```
  SELECT CityID, Name, Area FROM City;
  ```

- Give me all (column values of) rows of a table which fulfill certain conditions.

  ```
  SELECT CityID, Name, Area FROM City WHERE Area > 500;
  ```

- Give me all cities which are 'near' to Freiburg.

  ```
  SELECT CityID, Name FROM City WHERE ??????????;
  ```

How to combine (join) tables:

- Give me a listing of building addresses with name of the city.

```
SELECT City.Name, Building.Address FROM City, Building
WHERE City.CityID = Building.CityID;
```

- Compute all pairs of cities.

```
SELECT A.Name, B.Name FROM City A, City B
WHERE A.CityID <> B.CityID;
```

- Give me all cities which are 'near' to Kehl.

```
SELECT B.Name FROM City A, City B
WHERE A.Name = 'Kehl' AND ABS(A.Latitude - B.Latitude) < 0.5
AND B.Name <> 'Kehl';
```

- Give me all the readings of Kehl nicely sorted.

```
SELECT D.HouseholdID, D.FuelID, D.ReadingValue
FROM City A, Building B, Household C, Reading D
WHERE A.Name = 'Kehl' AND A.CityID = B.CityID
AND B.BuildingID = C.BuildingID AND C.HouseholdID = D.HouseholdID
ORDER BY D.HouseholdIG ASC, D.FuelID ASC, D.ReadingValue DESC;
```