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THE INVERSE APPROACH FOR NON REVENUE WATER MANAGEMENT

DIDIER CARRON (NALDEO)

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NALDEO

- French engineering and consulting firm
- 180 experts, specialized in Water, Solid Waste Management and Renewable Energy
- Fully independent

- Advisor for major performance based affermage contracts (also called management contracts) : SEDIF (Paris suburbs, population 5 M, amount of PPP = US$ 3 Billion), Lyon, Marseille, Bordeaux, Atyrau (Kazakhstan), etc

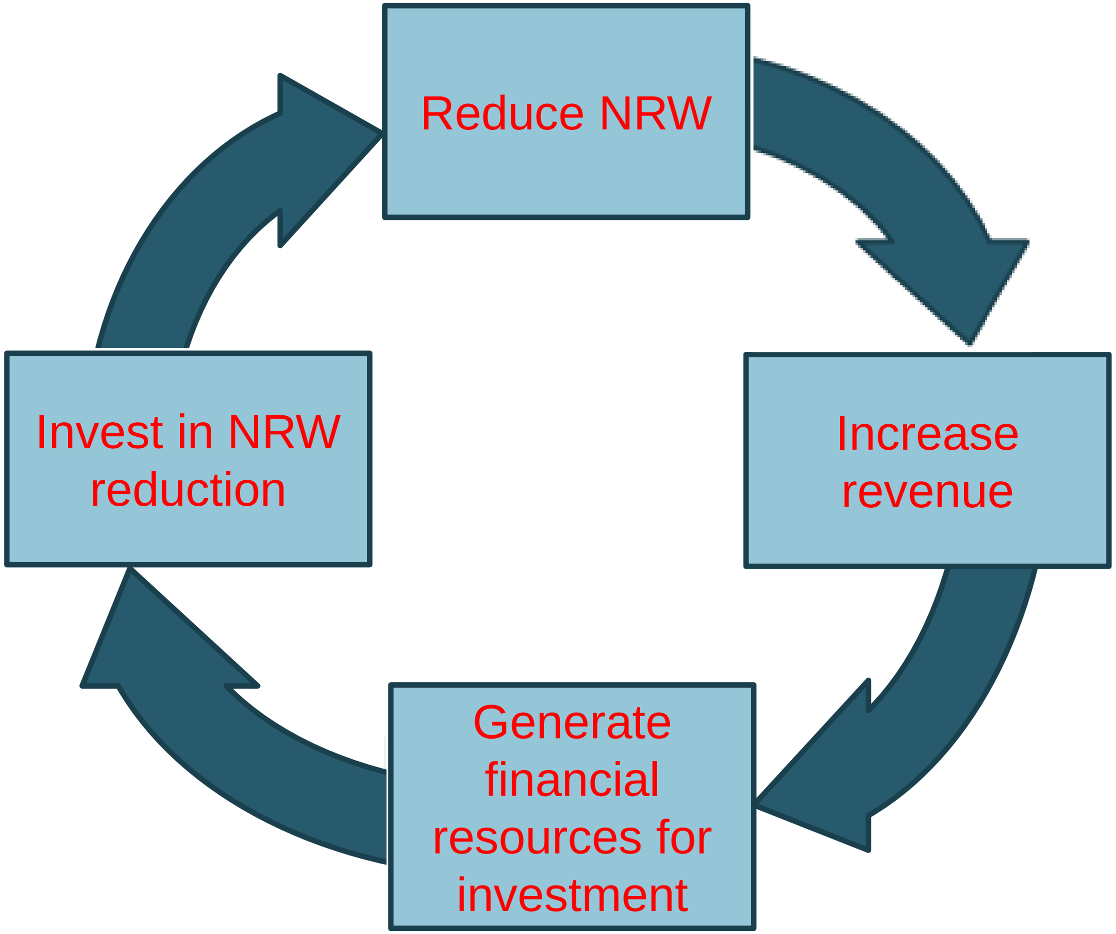
- Non Revenue Water (NRW) experience in France, Hanoi (AFD and WB), Oujda and Fes (ONEP), Burkina Faso (ONEA), Cabo Verde (MCC), Kenya (6 secondary towns, ongoing), etc

- Advisor for the creation of corporations for water management (Nice, etc)
- Annual audit of operation and R&D of several water services (SEDIF, Bordeaux, etc)

- Naldeo is active member of IWA – D. Carron is vice-chairman of the Performance Based Contract (PBC) task group
- Naldeo has been gold sponsor of IWA in 2013 and 2014, based on its work on PPPs and PBCs (performance based contracts).

REDUCTION OF NRW : A VIRTUOUS CYCLE

- Reducing NRW is a virtuous cycle



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NRW IS ALSO PART OF ASSET MANAGEMENT

- Definition of asset management by US EPA : *Asset management is maintaining a desired level of service for what you want your assets to provide at the lowest life-cycle cost.*

- Pipes are made to transport water with as less leaks as possible
- **Thus NRW is a Number One indicator for Underground Asset Condition Index (ACI)**

- For mature utilities, asset management represents up to 50 % of the cost of water

Amortization of civil works (pipes, plants)	0,32 €	0,73 €	52%
Staff for maintenance and renewal	0,13 €		
Amortization of equipment (renewal)	0,13 €		
Purchases for daily maintenance	0,15 €		
Operation staff	0,42 €	0,67 €	48%
Various expenses (energy, chemicals, offices, cars, insurance, IT, etc)	0,25 €		
1m3 of water	1,40 €		

About 50 % of the price of water is for asset management

HOW TO REDUCE NRW ?

- There are several ways to reduce Non Revenue Water

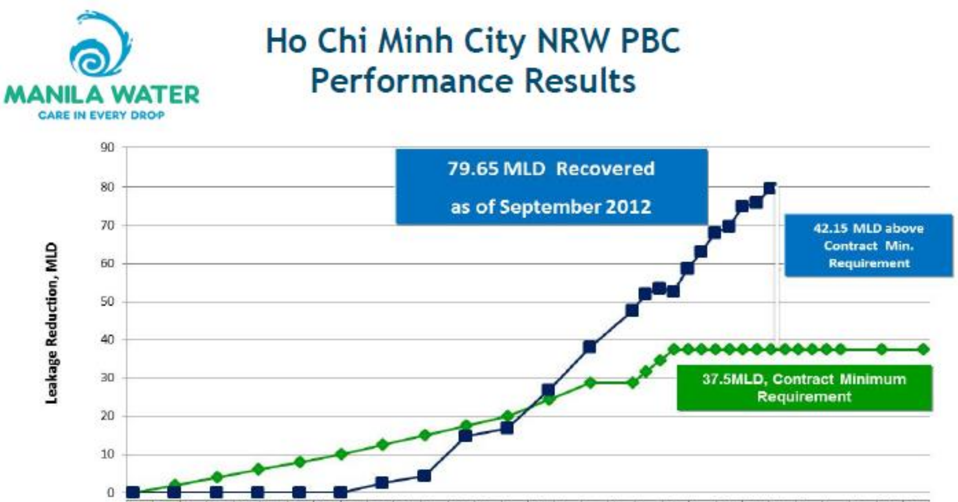
- **Main actions to reduce NRW include :**
  - Pressure management
  - Reduction of illegal connections
  - Zoning (District Meter Areas = DMAs) and active leakage control (leak detection and repair)
  - Pipe rehabilitation / pipe replacement
  - Meter replacement
  - Debt collection

CASE STUDY 1 – HO CHI MINH CITY (VIETNAM)

- Performance based contract in order to reduce physical leakage in Zone 1 of Ho Chi Minh City supply network

- Main actions have been
  - **Establishment of DMAs**
  - Leakage reduction and management services
  - New connections

- The results achieved were excellent :
  - 11 000 leaks were repaired leading to a volume of water saved as of August 2013 of more than 90 000 m3/day
  - More than 500 000 new customers became served



	Nov-08	Feb-09	May-09	Aug-09	Nov-09	Feb-10	May-10	Aug-10	Nov-10	Feb-11	May-11	Aug-11	Nov-11	Dec-11	Jan-12
Original Plan	0	2	4	6	8	10	12.5	15	17.5	20	24.4	28.8	28.8	31.7	34.6
Actual	0	0	0	0	0	0	2.6	4.4	14.9	17	26.8	38	47.7	52	53.5

	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	May-13	Aug-13
Original Plan	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Actual	52.7	58.6	63.1	68.0	69.7	74.9	75.9	79.7							

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CASE STUDY 2 – SAO PAULO (BRAZIL)

- SABESP serves the Sao Paulo Metropolitan Region – One of the largest water utility in the world (25 million)

- Performance based contracts.
- Main actions have been :
  - Debt collection : contractors paid 20 % of debt collected
  - **Meter replacement**

- The results achieved were very impressive :
  - Debt decreased from US$ 43 M to US$ 7M, mainly due to large customer (2 % of largest customers account for 34 % of revenue)
  - 27 000 meters replaced – fully prefinanced by contractors : Volume of metered consumption increased by 45 million m3
  - Revenues increased by US$ 72 M, out of which US$ 18 M were paid to the contractors

CASE STUDY 3 – EMFULENI (SOUTH AFRICA)

- Sebokeng and Evaton, part of Emfuleni Municipality - 50 km south of Johannesburg
- About 450,000 residents - Low and medium income
- NRW : estimated nearly 80 % before the project

- In a first stage, the Municipality decided to focus **on pressure management.** It was decided to regulate the pressure during off-peak periods in order to reduce water lost through leakage
- Fixing the leaks was considered to be rather done in a next phase.

- Performance Based Contact
- The split of gain was 80/20 project in favor of the Public Entity
- The funding for the project (0.5 M USD) was provided by the Contractors… due to the inability to secure any form of development funding from other institutions.

- The savings during the 5 years of the contract amounted to more than 50 million m3 in water purchases which translated to a saving of more than $20 million.
- The pay back period was about 2 years for the contractor and a few months for the Public Entity

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LESSONS

- **There is no one way to reduce NRW**

- Each action has
  - An investment cost
  - An operational cost
  - A short term effect on NRW
  - A Long term effect on NRW

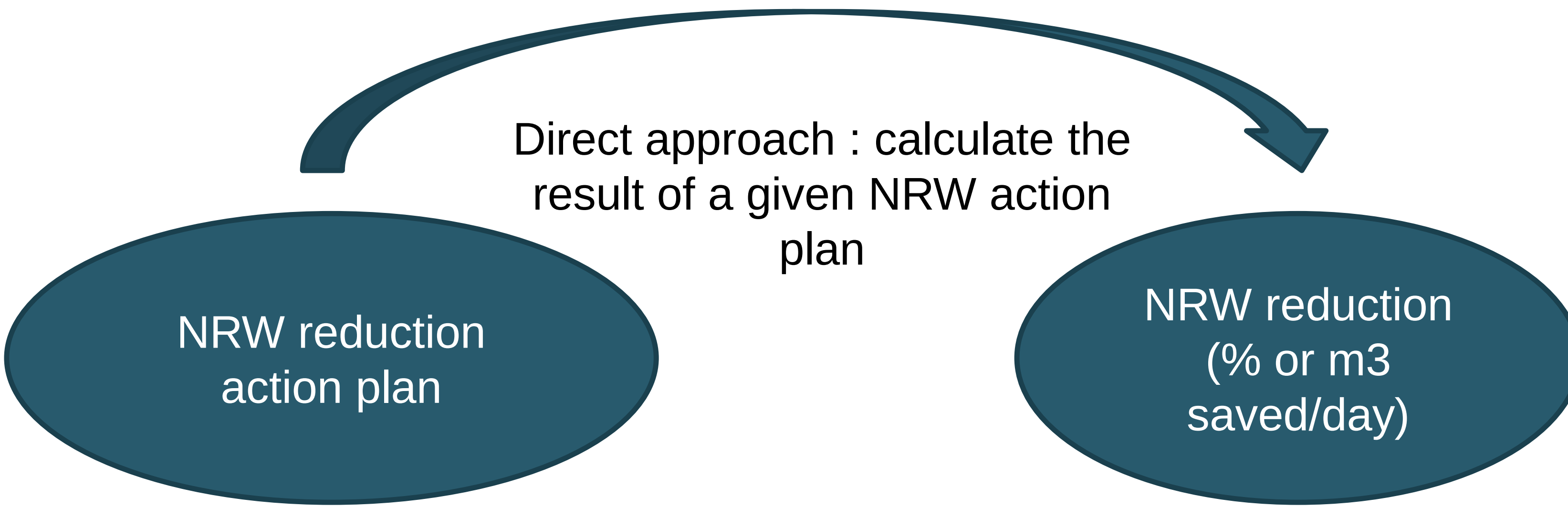
- **The challenge is to find the best mix of actions (= the less expensive mix) in order to achieve a NRW target in a sustainable manner**
  - How much of meter replacement every year ?
  - How many DMAs to implement every year ?
  - How much of pipe replacement every year ?
  - How much effort and financial incentives to decrease illegal connections ?

THE DIRECT APPROACH

- Based on
  - Available data from a utility
  - Experience from similar utilities

it is possible to write equations able to predict the effect (ie the reduction of NW) of a given action (for example replacing the meters)

- By combining several different actions you get the direct approach : calculate the effect of a given action plan



NRW reduction = f (action plan)

THE INVERSE APPROACH

- The inverse approach starts with the expected outcome (desired reduction in NRW) and calculates an action plan able to reach this result
- As there are many actions plans able to provide the same result, the goal is to find the less expensive action plan fitting with the targeted NRW reduction goal.

NRW reduction action plan 1

Action plans = f^{-1} (NRW reduction)

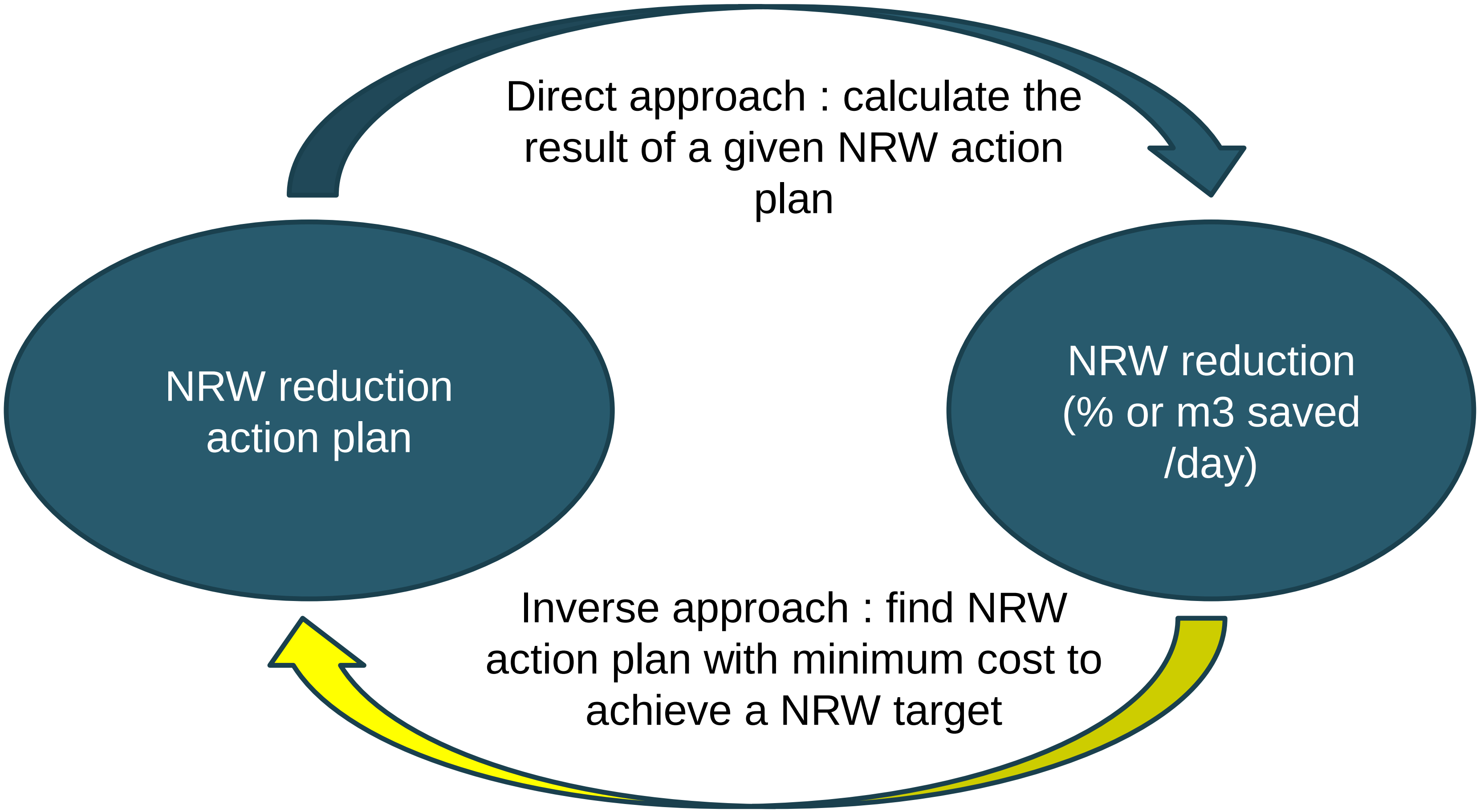
NRW reduction action plan 2

NRW reduction (% or m3 saved/day)

NRW reduction action plan 3

Choose the action plan providing the desired NRW reduction which is the less expensive

DIRECT AND INVERSE APPROACHES IN A SINGLE SLIDE

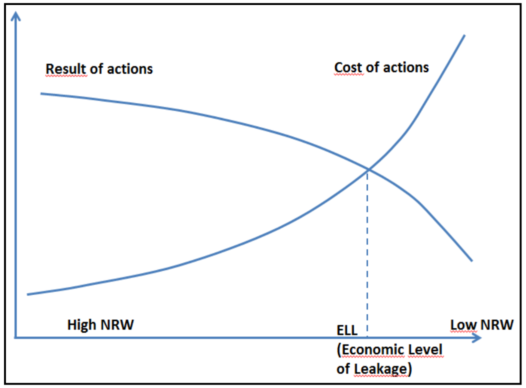


BUILDING THE DIRECT MODEL (1/2)

STEPS :

- Establish a baseline to evaluate the components of NRW (commercial losses, physical losses) = **establish a reliable water balance**

- Consider all actions that could be carried out to reduce NRW
- To each action considered to reduce NRW, is associated
  - A cost for implementation (US$)
  - An effectiveness on NRW reduction (m3/day)



- The cost and the effectiveness of each action will be based on :
  - The country (cost of labor, etc)
  - The initial network and commercial conditions
  - A key issue is that the cost and effectiveness of actions have to be made as a function of the current network and commercial conditions. **The model is thus dynamic**

WRC formula : $C = \frac{-1}{\delta}.\ln\left(\frac{V - V_{UARL}}{V_{PLL} - V_{UARL}}\right)$ avec $\delta = \frac{-1}{C_a}.\ln\left(\frac{V_a - V_{UARL}}{V_{PLL} - V_{UARL}}\right)$

BUILDING THE DIRECT MODEL (2/2)

- There is also the need for an **ageing model of assets**.

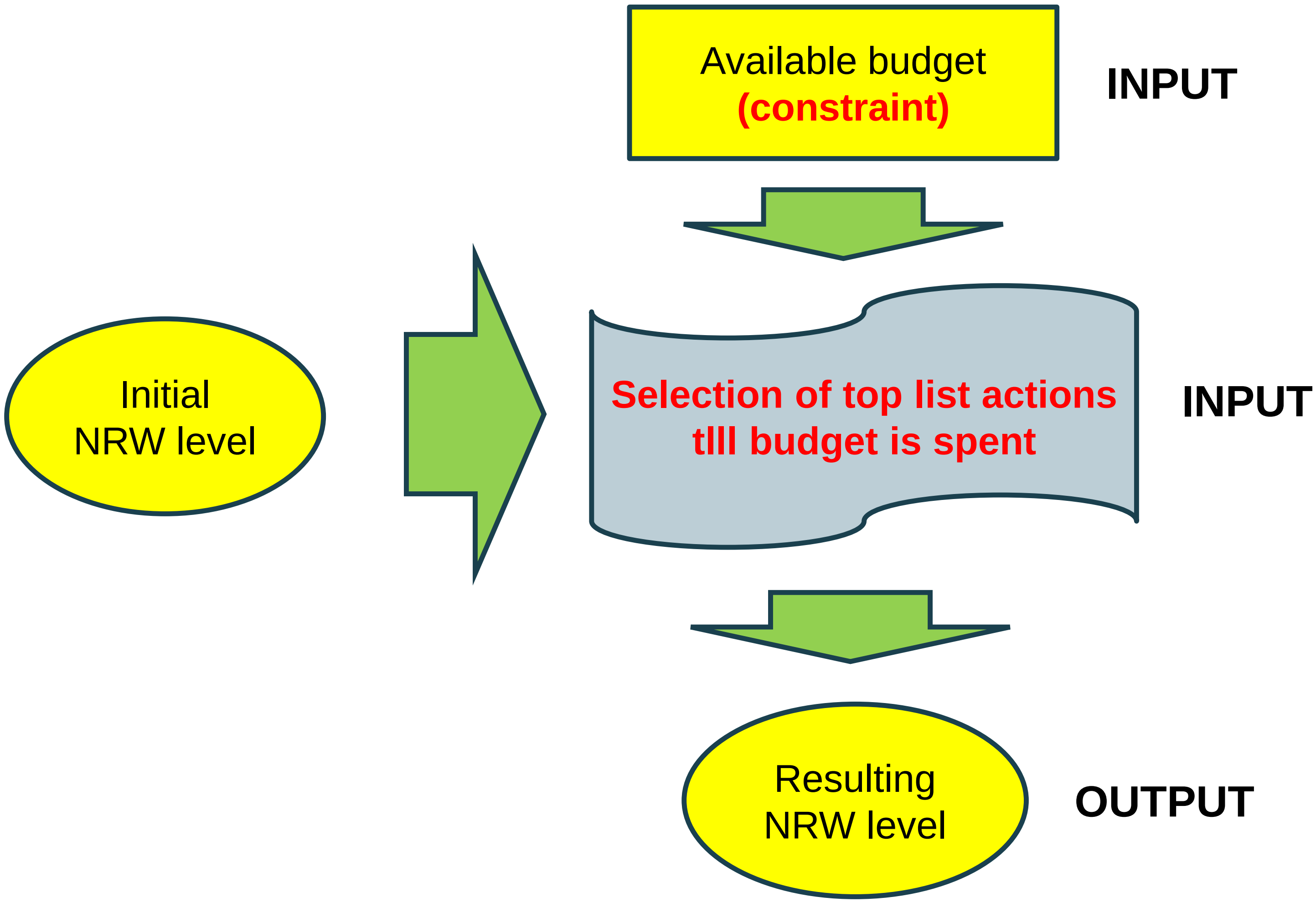
- Ageing models can be built by looking at the past
  - Analysis of risk failure of assets according to their age can be guessed from existing data
  - Alternatively the literature – including the UK Water Industry Research – suggests several laws for what is called the NRR = Natural Rate of Rise in Leakage.

- **By putting together** :
  - Dynamic effectiveness of each action
  - Cost of each action
  - Ageing model

we can build an economical model able to calculate the cost and the effectiveness of a NRW water action plan over a long period, such as 10 or 15 years

- **This is the "direct approach" : action plan -> NRW reduction (cost and effectiveness)**

THE DIRECT APPROACH



THE INVERSE APPROACH (1/4)

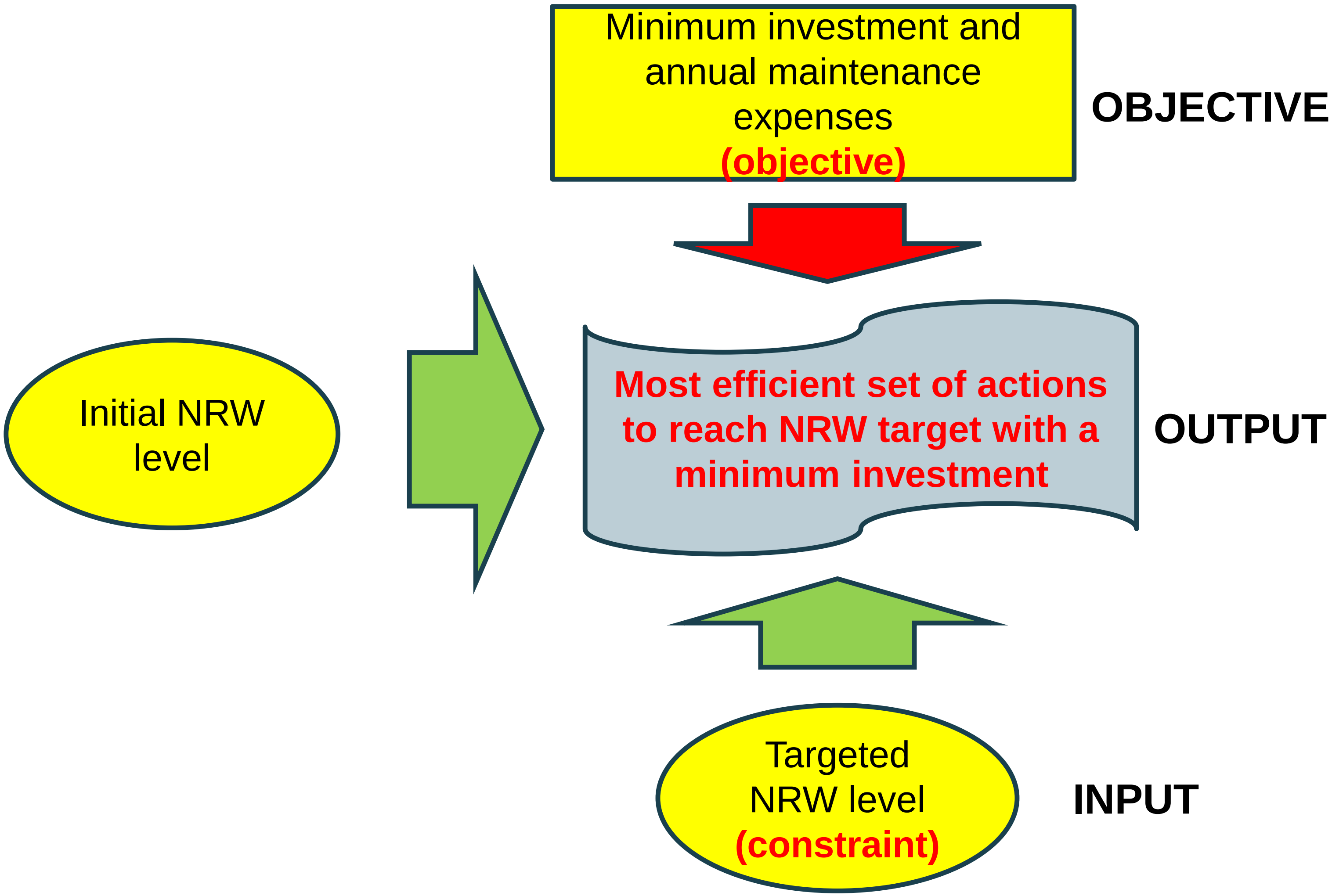
- The challenge now is to find the optimal set of actions (ie the asset management plan) :
  - providing the maximum effectiveness for a given amount of investment
  - OR
  - Being the less expensive for a given effectiveness (ie for a NRW value target)

- **This is the “inverse approach”**

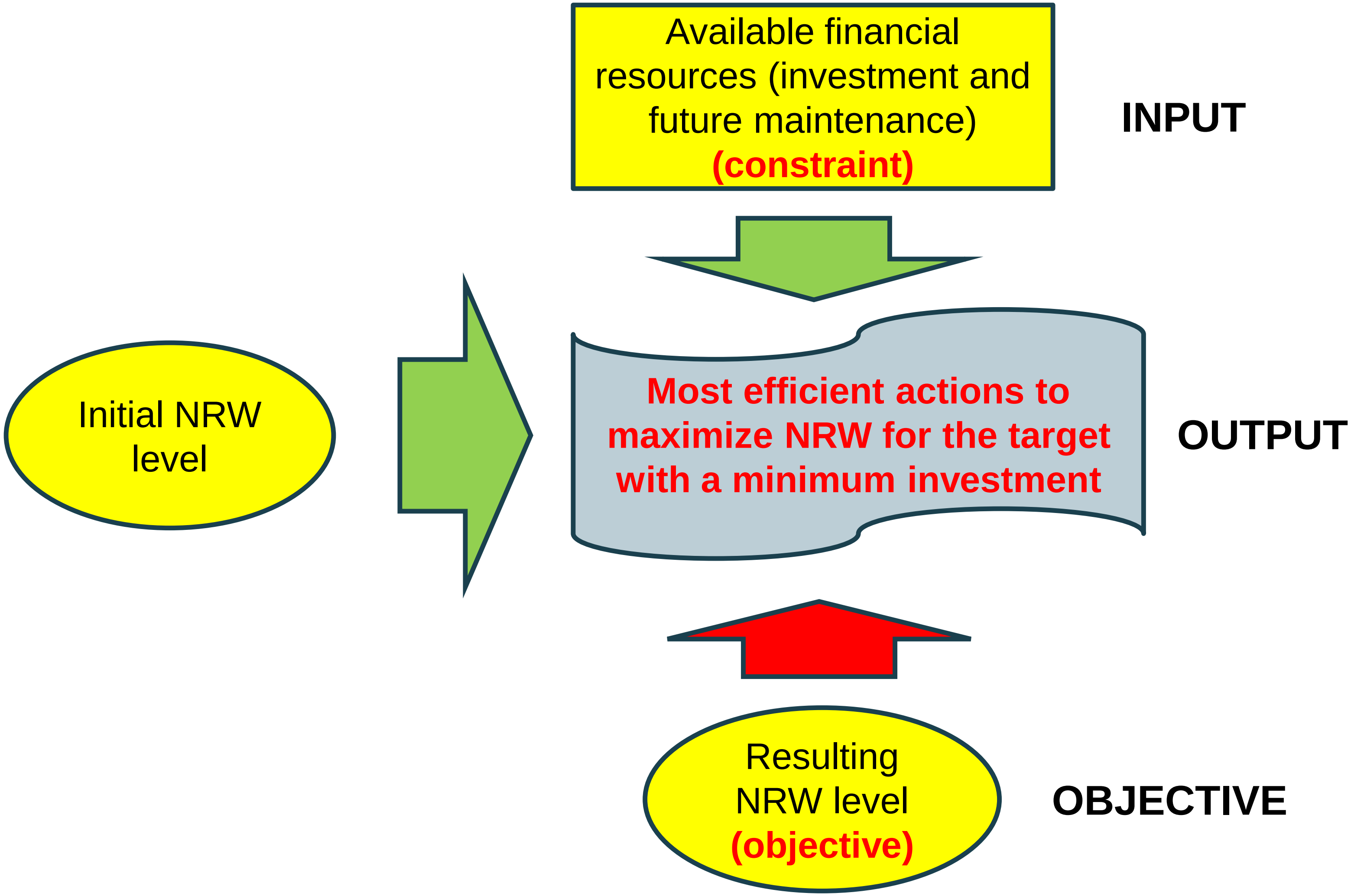
- **The inverse approach can be led under two schemes:**
  - A given amount of money (financial resources) is available, and one has to find the best action plan to have the maximum reduction of NRW
    - This can be funding for investment by an IFI and constraint on future tariff
    - **Financial resources driven approach**

  OR
  - A given NRW reduction is targeted, for example from a financial model providing expectations in revenue by the reduction of NRW) and one has to find the less expensive action plan to achieve this NRW reduction
    - **NRW reduction target driven approach**

THE INVERSE APPROACH (2/4) – NRW REDUCTION DRIVEN OPTION



THE INVERSE APPROACH (3/4) – FINANCIAL RESOURCES DRIVEN OPTION



THE INVERSE APPROACH (4/4)

- To find this optimal asset management plan (for optimal NRW reduction), there is a need to use an **optimization algorithm, which serves as a decision support model**.

- The optimization algorithm will test hundreds of different action plans using an appropriate heuristic and will be able to find the optimal NRW reduction action plan.

- From a mathematical point of view, the problem is said to be “non –linear”, **which implies that the use of rather fancy algorithms such as for example evolutionary algorithms (such as genetic algorithms) is necessary**
  - the solution is far from being obvious due to the dynamic nature of actions as a function of condition and the large number of variables in the calculation.
  - which means human brain cannot find the optimal solution

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CASE STUDY : WATER NETWORK MANAGEMENT IN THE CITY OF TROYES (1/3)

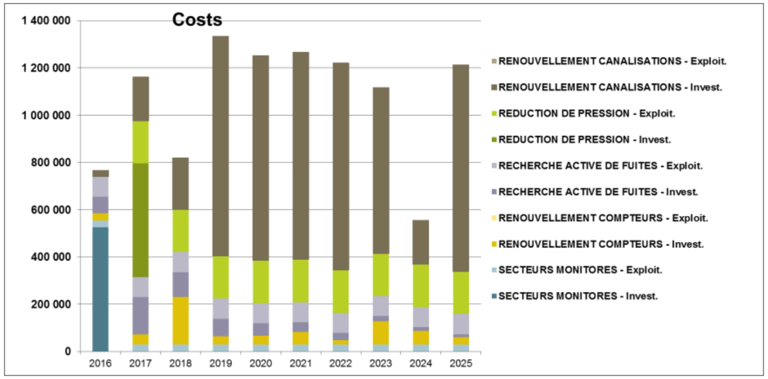
- Case study : town of Troyes in France
  - about 20 000 connections
  - Current NRW : 23 %
  - NRW Target = 15 % latest in 2023

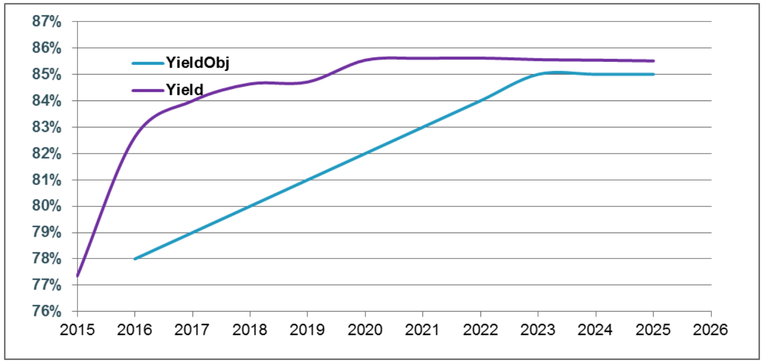
- The questions are:
  - What actions should be undertaken and when ?
  - What the (minimum) cost to reach this target ?

(Investment and maintenance)

CASE STUDY : WATER NETWORK MANAGEMENT IN THE CITY OF TROYES (2/3)

- The initial solution found by the model with the constraint that annual investment < 1,5 M€/year is the following :
- This is the best solution that can be found by the human brain, built by selecting first cheap actions (“low hanging fruits”, however not always sustainable) and later more expensive actions (but who will be very effective in the long run)

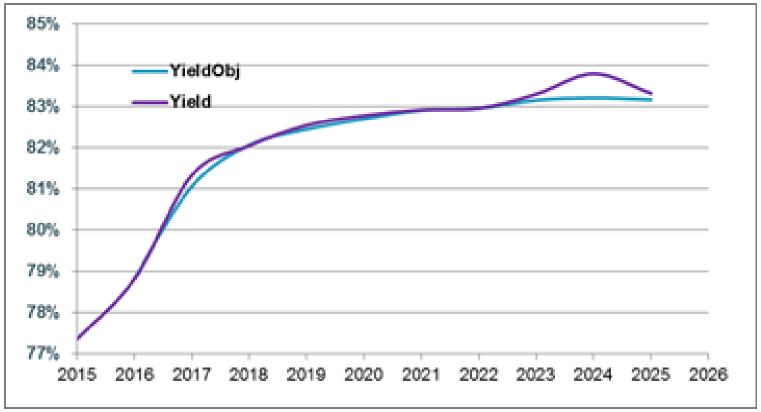


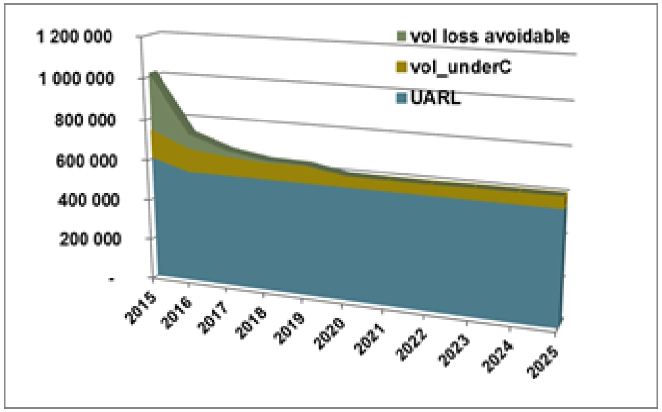


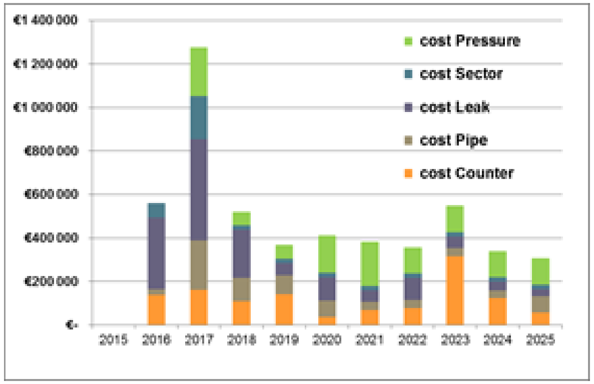
Initial action plan : Total cost : 10 705 968 €

CASE STUDY : WATER NETWORK MANAGEMENT IN THE CITY OF TROYES (3/3)

- Solutions found by the optimization module after many iterations :







Optimal action plan : Total cost of 5 064 418 €

TROYES CASE STUDY : CONCLUSION

- This case study demonstrates that by having a long term view and using an inverse approach, it is possible to find a sustainable action plan of about 5 M€ to reduce NRW from 23 % to 15 %, far better than the initial 10 M€ action plan initially established.

- **Discussion :**

- The solutions might be quite different according to the simulation period : 5 … 10 … 15 ….20 years
- This comes from the fact that long term actions, which include pipe replacement, are favored when considering a long period of times, as they bring improvement that will be sustainable.

- In order to come out of this process with a single action plan, it is possible to search to minimize the **Net Present Value (NPV)** instead of the total investment cost, with running the simulation over a very long period.

- In this case you end up with a single solution which is in line with typical financial logics.

CONCLUSION

- **Using the inverse approach makes it possible :**

- To get a comprehensive and long term view on NRW and select an optimal reachable and financially sustainable action plan.

- To "do more with less" : smart investment

- To provide a tool to :
  - The Operators, who can use this approach in order to select a NRW policy
  - The Contractors, who can use this approach to establish their proposal for NRW reduction
  - The Regulators, who can get a long term view on water supply capacities and possible development of level of service
  - The Financials and the Water Public Authorities, who can relate operational targets and financial resource, and thus fix a financial plan to support NRW reduction and select

Thank you for your attention.

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