# Game-changer

## Presented by:


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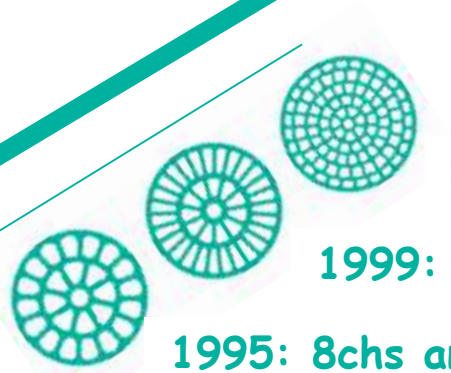
# Innovations for more performances

and now, what else can be done to do better ?



2012: 11chs and 93chs

1999: 39chs

1995: 8chs and 23chs

1995: non-circular cross section /rectilinear channels

TAMI Industries established 1993

1980s: cross flow filtration of liquids

Céramic membranes for gaseous diffusion

# What can be done to do better ?

**Market expectations = Competitiveness improving**

Performances L/h.m² and/or Energy consumption kWh/m³

⇓

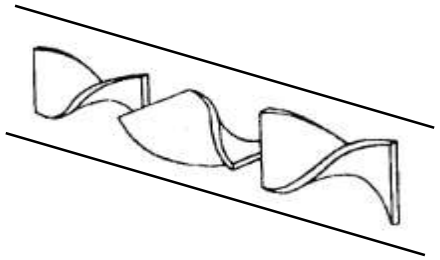
Concentration polarization and Membrane fouling => Wall shear stress $\tau_w$ (Pa)

# How to increase the wall shear stress ?

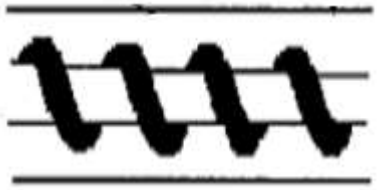
Turbulences are known for a long time to increase the wall shear stress…

① fluid velocity ↗ pressure drop ↗ ~~energy consumption~~

② insertion of promoters



static mixer. Krstic et All (2002)



helical baffle. Ahmad et All (2003)

but turbulences need

possible in lab, but not ~~INDUSTRIALLY~~

③ curved or spiral channels

Dean vortices in coiled tube. Moulin et All (1998)

but impossible by ~~EXTRUSION~~

thus anyone neither any company has yet be able to perform turbulences creation into industrial monolithic membranes

~~EXTRUSION~~

# ADDITIVE MANUFACTURING

a process which by building parts layer upon layer permits almost no limit to the morphology of monolithic parts

# From the idea (2012) to achievement through CFD simulations

**TAMI Industries investigated in deep in numerical simulations (CFD*) to design membranes "new generation"**

by using Navier-Stokes equations and « k-ω SST » model [1] to developp **a computational model** from which the « leak » (i.e. the **permeation flux**) is given by the relation:

$$J(\tau_w, \Delta P) = a.\tau_w + b.\Delta P + c + d.\tau_w.\Delta P$$

$\tau_w$ is the « wall shear stress », $\Delta P$ the « transmembrane pressure » and **a**, **b**, **c** and **d** are coefficients defined by integration of experimental measurements (real fluids) previously made in single channel membrane.

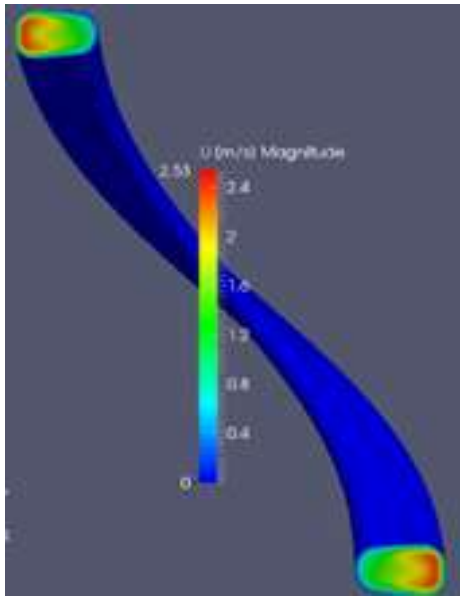
***Computational Fluid Dynamic**

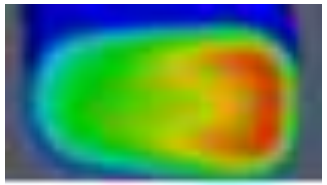
**[1] Menter, F. R. (1994), "Two-Equation Eddy-Viscosity Turbulence Models for Engineering Applications", AIAA Journal, vol. 32, no 8. pp. 1598-1605.**

# What kind of shape ?

For curved shaped channels, CFD simulations make possible to select the best shape by optimizing the curvature radii and the pitch of the helix for example when it's an helical shaped channel:

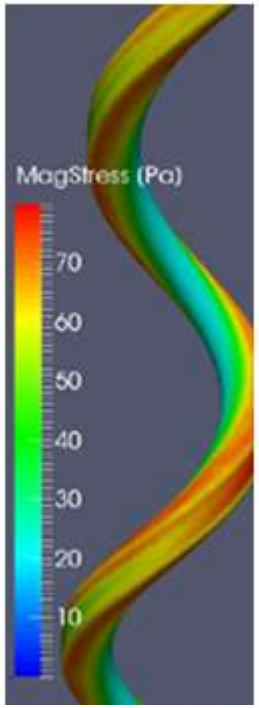
**Fluid cross flow velocity**



=>

**Wall shear stress**

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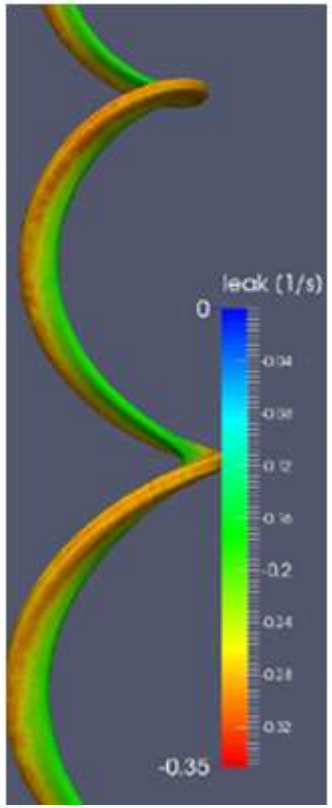
**Permeation flux**



# Multichannel example designed from several « single channels »:

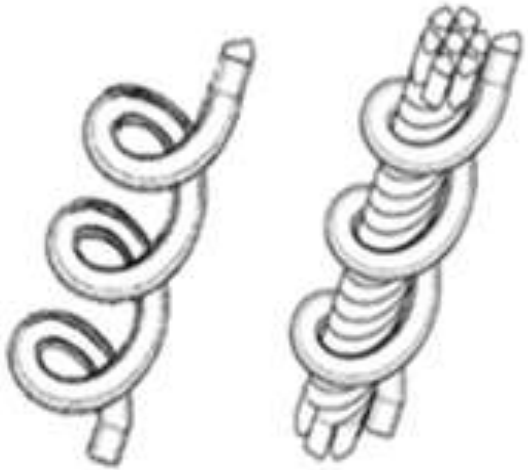
## Ø25mm - 23 channels (22 curved channels)

from one rectilinear channel

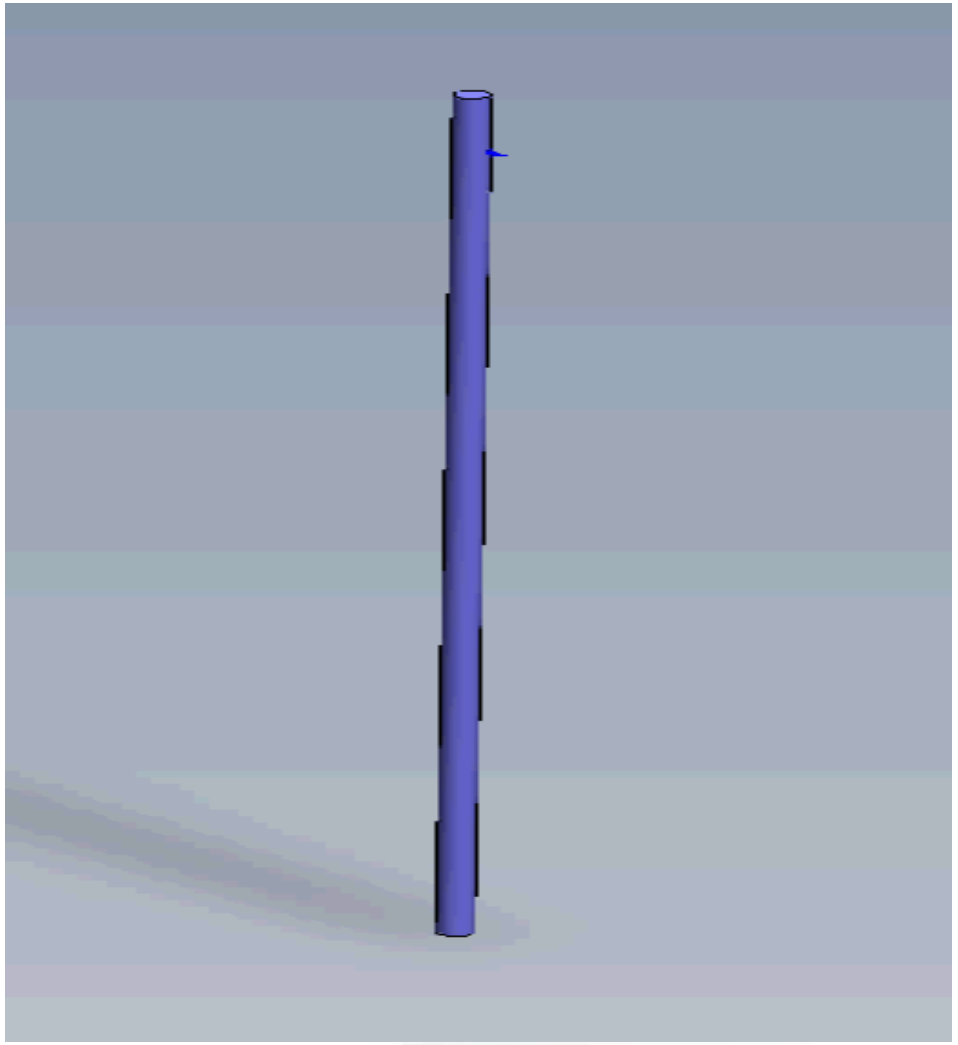
we design a first crown

x 6

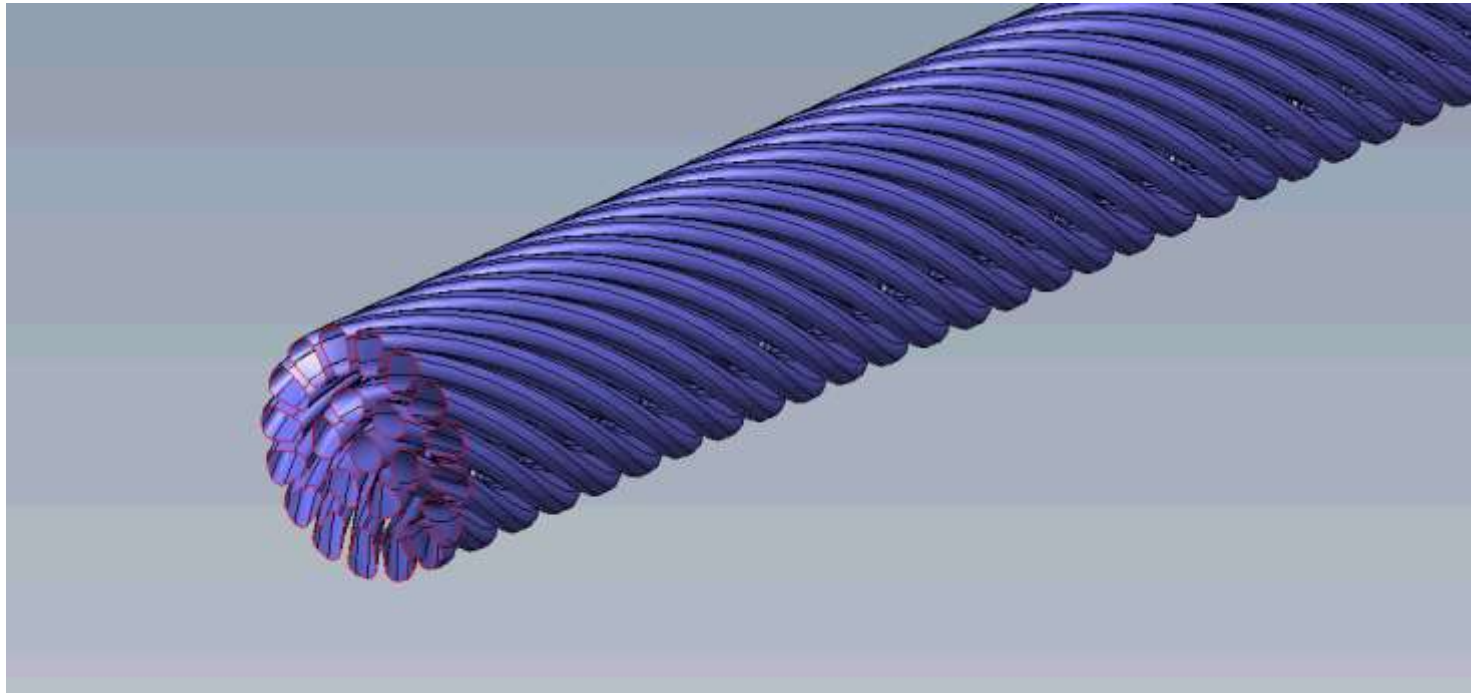
then a second crown



x 16



## … and the result is curvilinear flow lines

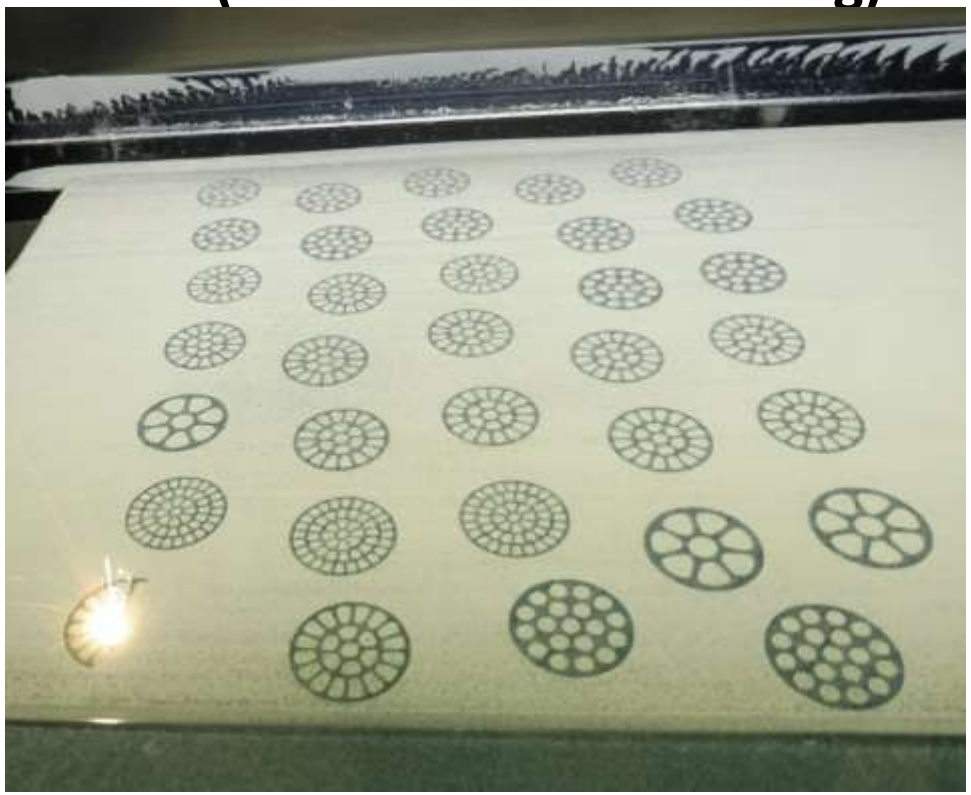


## into monolithic ceramics

## without visible external differences / extruded membranes

# examples of achievements

## SLS (Selective laser Sintering)



During laser scanning of one strate

## 3D printing (Binder jetting)

After printing and
before depowdering

# Filtration performances
## An example with red wine

New generation's membrane tested in direct comparison with the current generation's membrane

Test conditions :

material = ceramic

external diameter = 25mm

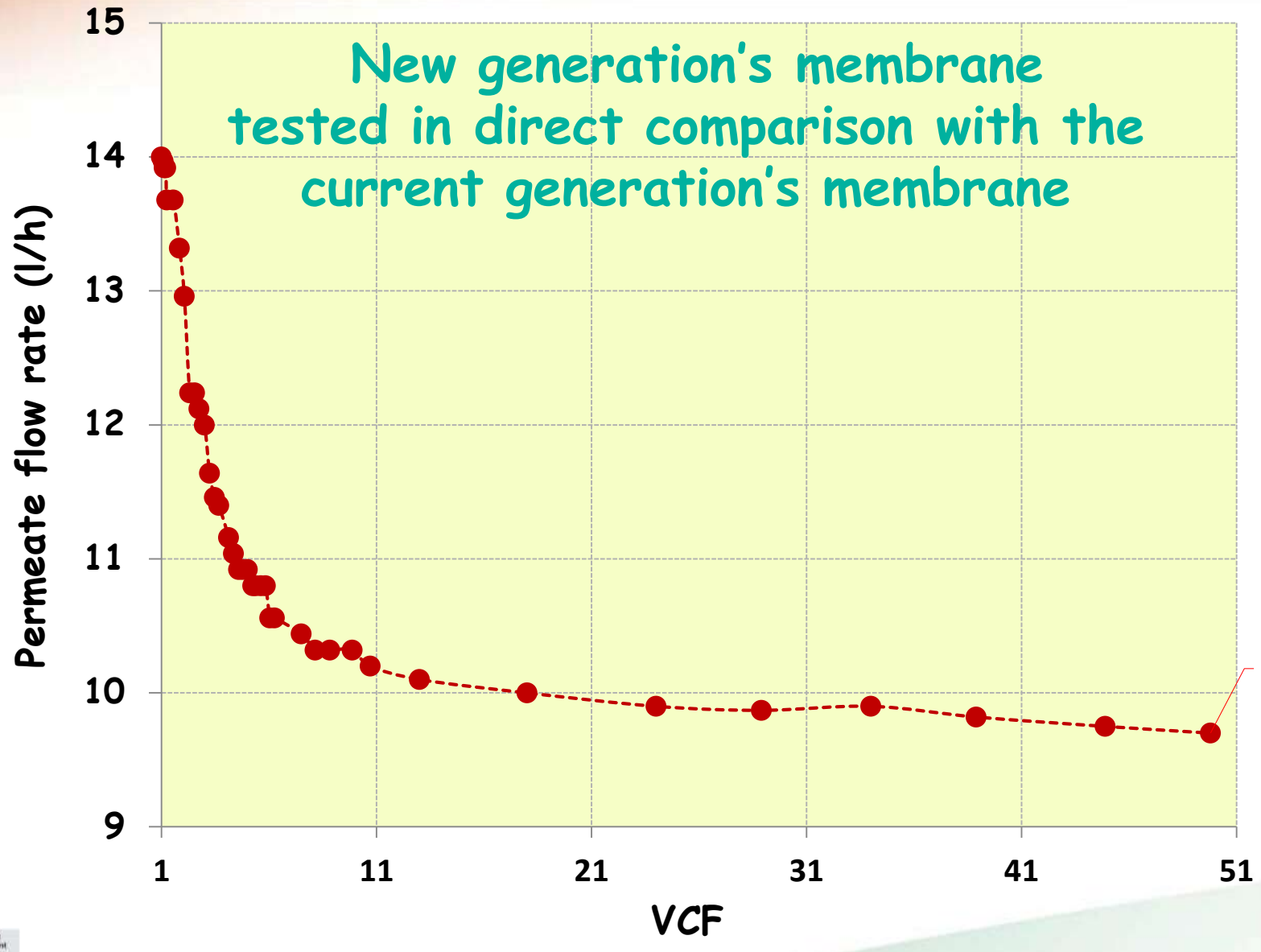
length = 900mm

number of channels = 23

hydraulic diameter = 3.5mm

cut off = 0.2µm

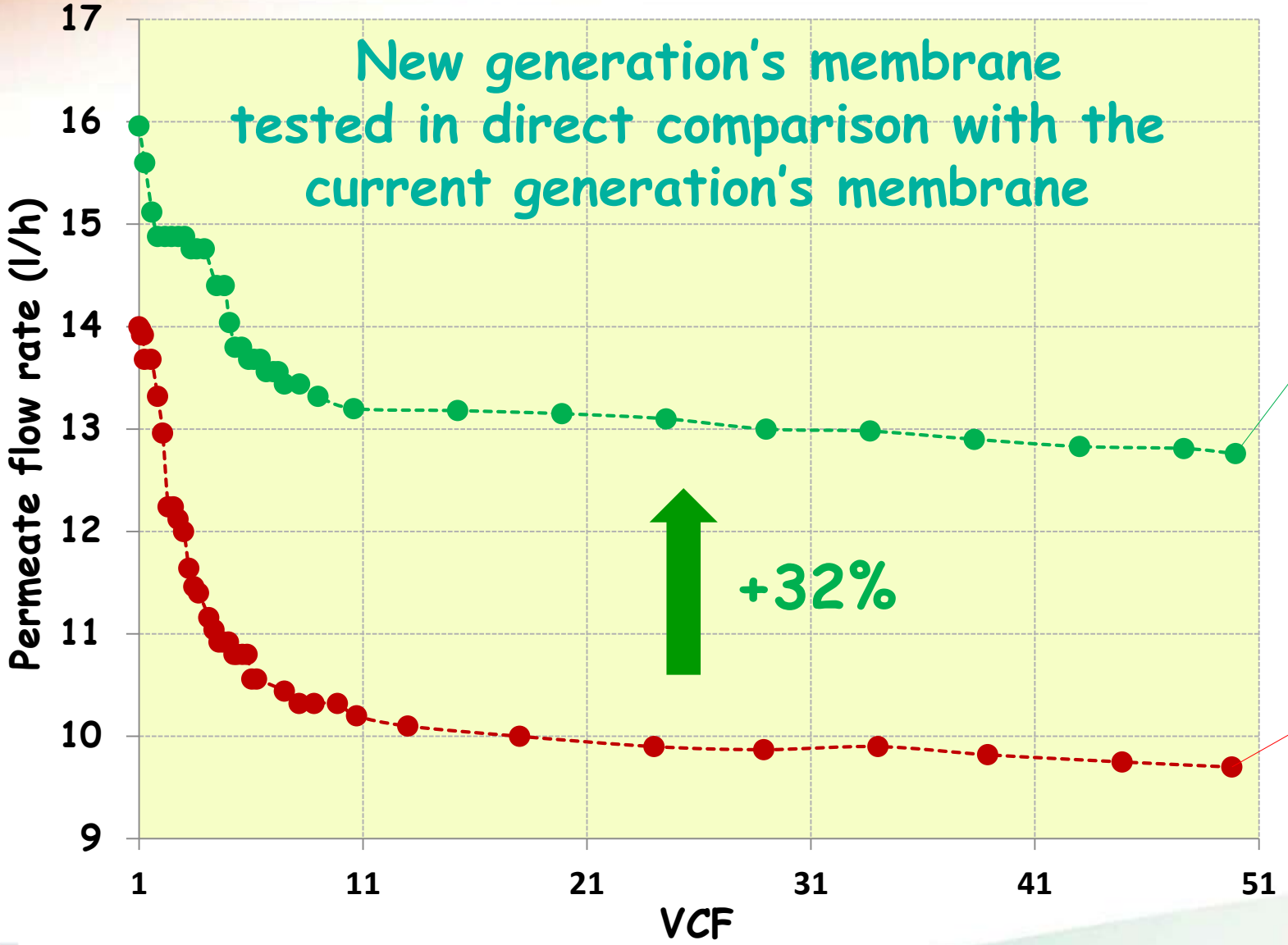
VCF (volume concentration factor) up to 50




Red wine
23 channels
Same length

Current generation
V=2.50m/s
P=19W

Extruded rectilinear channels




Red wine
23 channels
Same length

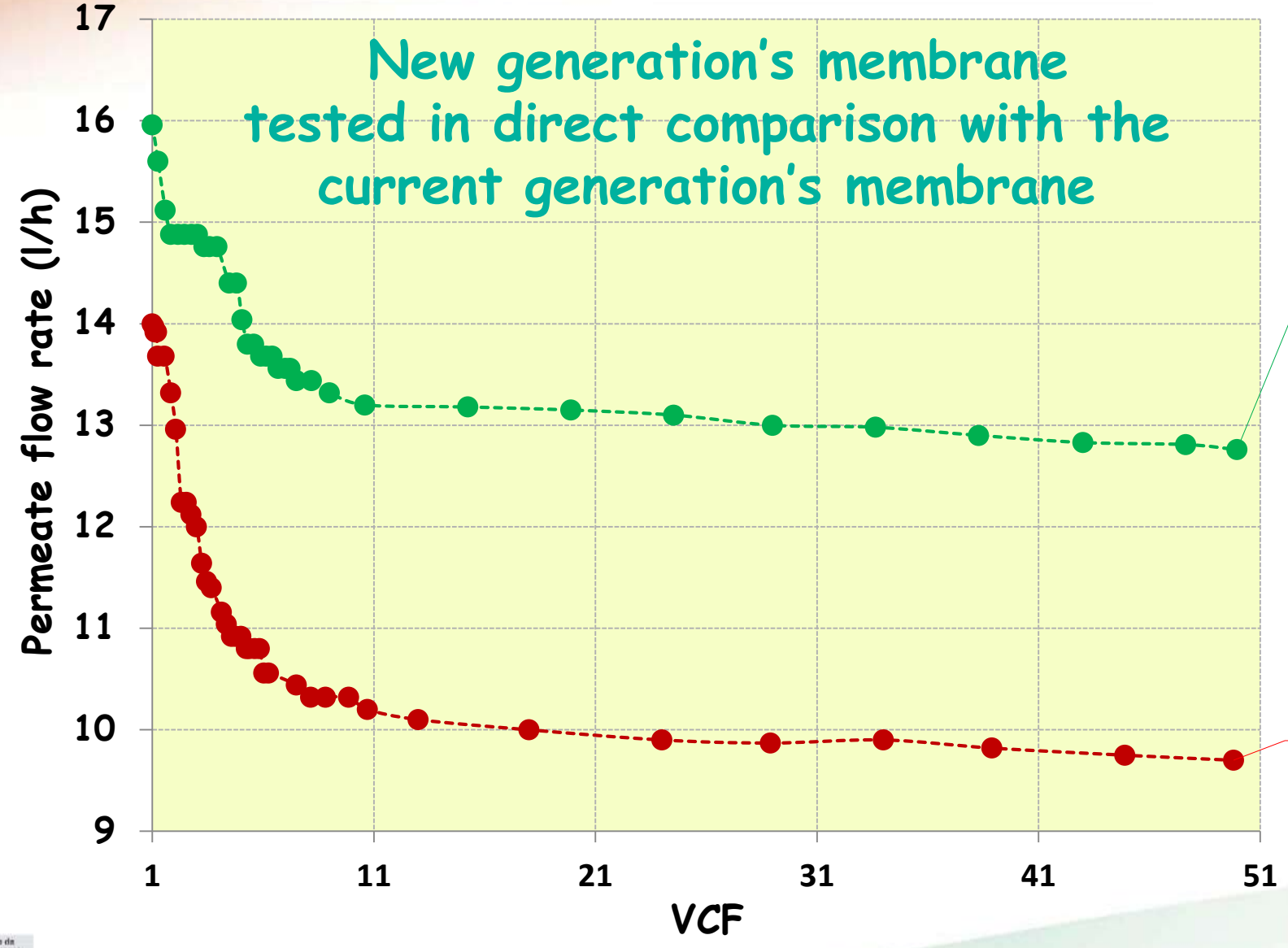
New generation

V=1.74m/s
P=19W

Current generation

V=2.50m/s
P=19W

same power= same energy consumption

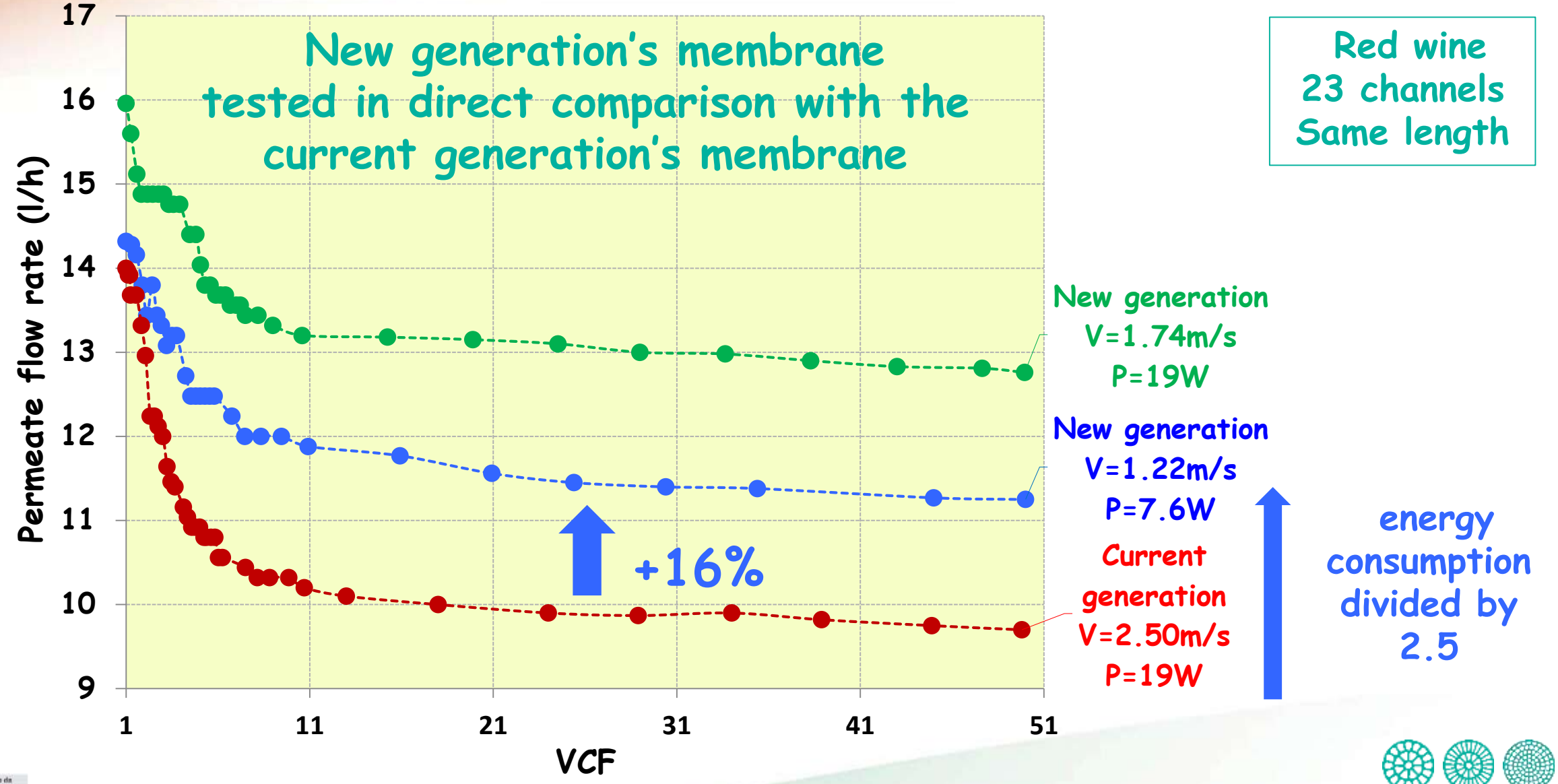



Red wine
23 channels
Same length

New generation
V=1.74m/s
P=19W

Current
generation
V=2.50m/s
P=19W

energy
consumption
divided by
2.5


New generation's membrane
tested in direct comparison with the
current generation's membrane
Red wine
23 channels
Same length
Permeate flow rate (l/h)
17
16
15
14
13
12
11
10
9
1
11
21
31
41
51
VCF
+16%
New generation
V=1.74m/s
P=19W
New generation
V=1.22m/s
P=7.6W
Current
generation
V=2.50m/s
P=19W
energy
consumption
divided by
2.5

By reducing fouling, despite a significant increase in pressure drop, this new filtration membranes innovate :

**by reducing energy consumption (W) while maintaining the same performance (L/h)**

or

**by increasing performance (L/h) while maintaining the same consumed energy (W).**

# Producing more with less energy

By making such new filtration membranes, TAMI Industries improves competitiveness by reducing cost in use of filtration units while reducing carbon footprint.

The result is a new way of thinking for inorganic and organic filtration membranes' conception and manufacturing thus an opening of new generation for membranes.

The production of filtration elements by using additive technologies, with all the possibilities given by them, already protected by TAMI Industries with international patents, will allow in a very near future to complete the current ranges by supplying new generations of laboratory and then industrial products.